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Operations Research Society of America

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1963-1964

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BULLETIN

OF THE

Operations Research Society of America

Supplement 1 OPERATIONS RESEARCH Volume 12, 1964

Program of the Joint CORS-ORSA Conference

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The CORS-ORSA 1964 Joint Conference

Montreal, Canada. May 27–29, 1964

REGISTRATION INFORMATION

Registration

The registration desk will be located in the foyer of the convention floor of the Queen Elizabeth Hotel. The registration schedule will be:

Tuesday, May 26th 5:00 p.m. to 10:00 p.m.
Wednesday, May 27th 8:00 a.m. to 10:00 a.m.

A Hospitality Room will be open on Tuesday evening and Wednesday morning where speakers can meet with their session chairman.

* Fees

Registration		Functions	
Member	$10.00	Luncheon, Wednesday	$4.25
Non-member	$15.00	Wine & Cheese Tasting Party, Wednesday	$5.00
Student	$2.00	Reception, Thursday	$2.00
		Banquet, Thursday	$6.50
		Luncheon, Friday	$4.25

* Canadian Funds.

Advance Registration

Advance registration is encouraged. It will enable you to pay fees and receive materials at the pre-registration desk with minimum inconvenience. A list of all advance registrants will be distributed at the meeting. Do not pay fees in advance. Please mail completed meeting registration cards to:

Dr. G. Cavadias,
Graduate School of Business,
McGill University,
1020 Pine Avenue West,
MONTREAL, P.Q.
CANADA.

Accommodation

A block of rooms has been reserved at the Queen Elizabeth Hotel, on Dorchester Boulevard, Montreal, P.Q. A reservation card is included with this bulletin and, when completed, should be sent directly to the hotel.

The hotel has excellent parking accommodations for all guests and is located in the heart of down-town Montreal. The Hotel itself, (60 on the tourist map included with the *Bulletin*), is at the corner of Dorchester and Mansfield streets, opposite the *Place Ville Marie*, Montreal's largest skyscraper, and adjacent to the Canadian National Railways Central Station and the airlines limousine terminal at Dorchester and University.

Additional rooms have been reserved at the Laurentien Hotel (64 on the map) at Dorchester and Windsor streets, one block from the Queen Elizabeth. Other nearby hotels are the Windsor, (54 on the map) Windsor St. just north of Dorchester and the Sheraton Mount Royal (47) at Peel and Burnside.

The closest motel is the Martinique Motor Inn, opening May 15th at 1005 Guy St. near Dorchester.

Accommodation at the Queen Elizabeth is limited for the night of Tuesday, May 26th. All hotel reservations should reach the hotel at least 14 days before the room is required.

Transportation

Limousine service goes directly between the hotel and the Dorval airport. Passenger train services arrive at either Central Station or Windsor Station.

Employment Notices

As in the past, employers will be permitted to display notices of available positions in Operations Research. However, such notices must be given to the Facilities Chairman, Mr. C. E. Law, for posting; and are limited to maximum dimensions of 8½ inches in height and 11 inches in width.

Lady's Program

Delegates are encouraged to bring their wives. Montreal provides excellent shopping and has many points of interest including an Art Gallery, Wax Works and numerous museums. It also has a number of good antique shops and smaller private art galleries.

A complete, yet optional lady's program is being arranged, whereby wives once they have indicated their preferred activities, will be assigned to a hostess, who will escort them around the city.

Copies of Papers

Requests for copies of papers should be made directly to the authors. Their addresses are given in the body of the program schedule. Do not write to the Program Chairman, Secretary of the Society or the Editor of the Bulletin; they do not have copies of papers available for distribution.

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Transportation & Science Section Program Chairman:	P. Wilson, *Canadian National Railways, P.O. Box 8100,* *Montreal, P.Q.*

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CHAIRMEN FOR TECHNICAL SESSIONS

2Wa. ALEC LEE, *Director of Operational Research, Trans-Canada Air Lines, Place Ville Marie, Montreal, P.Q., Canada.*

2Wb. BEN BERNHOLTZ, *Department of Industrial Engineering, University of Toronto, Toronto 5, Ont., Canada.*

2Wc. R. G. BELCHER, *Canadian International Paper, 2020 Sun Life Building, Montreal, P.Q., Canada.*

2Wd. JACK B. COURSEY, *Research Triangle Institute, Durham, North Carolina.*

3Wa. ALEC LEE, *Director of Operational Research, Trans-Canada Air Lines, Place Ville Marie, Montreal, P.Q., Canada.*

3Wb. BEN BERNHOLTZ, *Department of Industrial Engineering, University of Toronto, Toronto 5, Ont., Canada.*

3Wc. R. G. BELCHER, *Canadian International Paper, 2020 Sun Life Building, Montreal, P.Q., Canada.*

3Wd. WALTER HELLY, *The Port of New York Authority, 111 Eighth Avenue, at 15th Street, New York, N. Y.*

3We. WALTER EDWARD CUSHEN, *Institute of Defense Analysis, Economics and Political Studies Division, 1666 Connecticut Avenue N.W., Washington 9, D. C.*

4Wa. ALEC LEE, *Director of Operational Research Trans-Canada Air Lines, Place Ville Marie, Montreal, P.Q., Canada.*

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4Wd. WALTER HELLY, *The Port of New York Authority, 111 Eighth Avenue at 15th Street, New York, N. Y.*

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1Ta. DAVID NOVICK, *Head—Cost Analysis Department, RAND Corporation, 1700 Main Street, Santa Monica, California.*

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4Fc. Charles Jones-Whittey, *Northern Electric Co. Ltd., P.O. Box 6123, Montreal, P.Q., Canada.*

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CORS Presidential Address—ARTHUR W. PORTER,
Chairman: JOHN R. WALTER
ORSA Business Meeting:
Chairman: ALEXANDER M. MOOD
Banquet—"SOVIET RESEARCH": DR. O. M. SOLANDT
ORSA Presidential Address—ALEXANDER M. MOOD
Chairman: GORDON D. SHELLARD

SYNOPSIS OF THE CORS/ORSA MONTREAL MEETING

A fold-out attached to the inside back cover of this issue of the *Bulletin* provides a complete *Synopsis of the Montreal Meeting.*

The reader will note that a special Program Code has been devised by the Conference Committee to ease the usual problems of locating desired papers and the time of their presentation. This code has been applied uniformly in the *Synopsis, Index of Participants, Program,* and *Abstracts.* Thus, complete cross-reference is available.

The Program code indicates (from left to right) the time block, day of session, room location, and paper number within session. An asterisk (*) before any paper indicates that it is *invited,* rather than contributed.

Time blocks 1 and 2 are in the morning; blocks 3 and 4 are in the afternoon. The code **W, T,** or **F,** indicates Wednesday, Thursday, or Friday. The room locations are designated **a, b, c, d,** or **e.** These rooms, all on the main convention floor of the Queen Elizabeth, are marked by large signs (see Synopsis) indicating their alphabetic designation.

As an example, **3Ta.2** (the illustrative case given in the Synopsis) indicates this paper will be given between 2:00–3:30 in the afternoon, on Thursday, in Room a, and is the second paper in that time block. Reference to the Program listing indicates this paper to be **Stochastic Nature of Military Cost Analysis,** by ALFRED G. ASWAD, *Douglas Aircraft Company, Inc., Santa Monica, California.*

In the Program, papers are listed in the sequence: day, time block, room, paper number. In the fold-out Synopsis, the same order is preserved with a page for each day, a colume for each time block, and a row for each room location. General Session titles appear in the Synopsis: for detailed paper and author listing within a given session, the main body of the Program must be consulted.

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* Means invited session or discussant.

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* Means invited session or discussant.

(Note: For a list of session and other functions chairmen, please see list of chairmen.)

PROGRAM

WEDNESDAY MORNING, MAY 27

REGISTRATION: 8:00–10:00 a.m.
Convention floor mezannine

WEDNESDAY MORNING, MAY 27

COFFEE BREAK: 9:45–10:15 a.m.
Courtesy of: *Computing Devices of Canada Limited*

WEDNESDAY MORNING, MAY 27

Session 2Wa. 10:15–12:15 p.m.

Simulation

Chairman: ALEC LEE, *Trans Canada Air Lines*

2Wa. 2. The Statistical Properties of Large Battle Simulations, FRANKLIN C. BROOKS, *Technical Operations Inc., South Avenue, Burlington, Massachusetts.*

2Wa. 3. Command: A Model of a Network of Command Systems, R. M. LONGMIRE, *Development Division, System Development Corp., 2500 Colorado Avenue, Santa Monica, California.*

2Wa. 4. Modeling and Simulation as a Research Tool, WARREN A. JOSLYN, *Systems Research, The Boeing Company, P.O. Box 3707, Seattle 24, Washington.*

WEDNESDAY MORNING, MAY 27

Session 2Wb. 10:15–11:45 p.m.

Real Time Control Systems

Chairman: BEN BERNHOLTZ, *University of Toronto*

* **2Wb. 1. Centralized Traffic Control by Digital Computers,** DR. J. KATES, *Traffic Research Corporation, 20 Spadina Road, Toronto 4, Ontario.*

* **2Wb. 2. Real-Time Control on Interconnected Power Systems,** R. D. NEVISON, *Assistant Production Engineer, Operating Department, Ontario Hydro.*

WEDNESDAY MORNING, MAY 27

Session 2Wc. 10:15–12:15 p.m.

Theory and Special Models

Chairman: R. G. Belcher, *Canadian International Paper*

2Wc. 1. **On a Mixed-Sequential Estimating Procedure with Application to Audit Tests in Accounting,** A. Charnes, *Northwestern University, Research Professor of Applied Mathematics and Economics, Evanston, Illinois;* H. Justin Davidson, *Touche, Ross, Bailey and Smart;* K. Kortanek, *Northwestern University and the University of Chicago.*

2Wc. 2. **Bayesian Operations Research,** Lockwood Rianhard, Jr., *Assistant Professor, State University of New York at Buffalo, Crosby Hall, Library Circle, Buffalo 14, New York.*

2Wc. 3. **On the Principle of Maximizing Entropy,** Donald J. Clough, *Department of Industrial Engineering, University of Toronto, Toronto 5, Ontario.*

2Wc. 4. **Independence in Utility Theory,** Peter C. Fishburn, *Research Analysis Corporation, McLean, Virginia, 6935 Arlington Road, Bethesda 14, Maryland*

WEDNESDAY MORNING, MAY 27

Session 2Wd. 10:15–12:15 p.m.

Textile Industry

Chairman: Jack B. Coursey, *Research Triangle Institute*

* 2Wd. 1. **Survey of Operations Research in Textiles,** Jack B. Coursey, *Operations Research Analyst, Research Triangle Institute, Durham, North Carolina.*

* 2Wd. 2. **Product Line Strategy in Style Merchandising,** Kurt H. Schaffir, *Arthur Andersen & Company, 80 Pine Street, New York 5, N. Y.*

* 2Wd. 3. **Flow Analysis of Variations with Applications to Textile and Other Industries,** Dr. Norbert Lloyd Enrick, *University of Virginia, Charlottesville, Virginia.*

* 2Wd. 4. **How to Make Rough Models of Complex Systems,** C. F. Miller III, and D. S. McArthur, *Deering Milliken Service Corporation, Spartanburg, South Carolina.*

WEDNESDAY AFTERNOON, MAY 27

LUNCHEON: 12:30 p.m.

CORS Presidential Address

Speaker: ARTHUR W. PORTER, *Canadian Operational Research Society*

Chairman: JOHN R. WALTER

WEDNESDAY AFTERNOON, MAY 27

Session 3Wa. 2:00–3:30 p.m.

Simulation (Continued)

Chairman: ALEC LEE, *Trans Canada Air Lines*

3Wa. 1. A Relationship Between Decision Making Penalty and Simulation Sample Size, M. E. BRENNER, *Bell Telephone Laboratories, Inc., Holmdel, New Jersey.*

3Wa. 2. Testing the Overall Sensitivity of the Mathematical Model, J. C. NAPOLI, *Plans and Systems Analysis, Douglas Aircraft Company, Long Beach, California.*

3Wa. 3. COG: Combinatorial Optimum Generating, WINSTON RILEY III, *C.E.I.R. Inc., 1200 Jefferson Davis Highway, Arlington, Virginia.*

WEDNESDAY AFTERNOON, MAY 27

Session 3Wb. 2:00–3:30 p.m.

Real Time Control Systems (Continued)

Chairman: BEN BERNHOLTZ, *University of Toronto*

* **3Wb. 1. Survey of Dynamic Optimization Techniques,** DR. MURRAY WONHAM, *Center for Control Theory, Research Institute for Advanced Studies, 7212 Bellona Ave., Baltimore 12, Maryland.*

* **3Wb. 2. On-line Process Control Computers and Operations Research,** T. M. STOUT, *TRW Computer Division, 8433 Fallbrook Avenue, Canoga Park, California.*

WEDNESDAY AFTERNOON, MAY 27

Session 3Wc. 2:00–3:30 p.m.

Theory and Special Models (Continued)

Chairman: R. G. BELCHER, *Canadian International Paper*

3Wc. 1. **Minimax Solutions of Problems on Distributions of Search Effort,** ALBERTO RAUL GALMARINO, *Associate Professor in Mathematics, Northeastern University, Room 418U, Boston 15, Massachusetts.*

3Wc. 2. **A General Antisubmarine Attack Model,** DR. ALEX HERSHAFT, *Operations Evaluations Group, Center of Naval Analyses of the Franklin Institute, Navy Department, Washington 25, D. C.*

3Wc. 3. **An Analysis of Re-Entry Vehicle Defense Penetration,** HAROLD C. SEBRING, Advanced Space Projects Department, *Room 7246-CCF #7, General Electric Co., P. O. Box 8661, Philadelphia 1, Pennsylvania.*

3Wc. 4. **Non-heuristic Methodology for Determining Optimum Logistics Support for Manned Orbiting Space Laboratories,** ROBERT F. BURNES, *Operations Research Assistant, Lockheed Aircraft, Corporation, California Division, Burbank, California.*

WEDNESDAY AFTERNOON, MAY 27

Session 3Wd. 2:00–3:30 p.m.

Transportation Science Section of ORSA

Chairman: WALTER HELLY, *The Port of New York Authority*

* 3Wd. 1. **On Flow Within Platoons,** ARTHUR DAOU, *The Port of New York Authority, 111 Eighth Avenue at 15th Street, New York, N. Y.*

* 3Wd. 2. **The Dependence Between Vehicles in Single-Lane Flow,** HAROLD GREENBERG, *New York University, New York 53, N. Y.*

* 3Wd. 3. **Single-Lane Bus Flow,** R. ROTHERY, R. SILVER and R. HERMAN, *Research Laboratories, and* C. TORNER, *Styling Staff, General Motors Corporation, Warren, Michigan*

WEDNESDAY AFTERNOON, MAY 27

Session 3We. 2:00–3:30 p.m.

Chairman: WALTER E. CUSHEN, *Institute of Defence Analysis*

3We. 0. **National Cost Effectiveness Analysis—Work Session**

WEDNESDAY AFTERNOON, MAY 27

BREAK: 3:30–3:45 p.m.

WEDNESDAY AFTERNOON, MAY 27

Session 4Wa. 3:45–5:15 p.m.

Simulation (Continued)

Chairman: ALEC LEE, *Trans Canada Air Lines*

4Wa. 1. **A Fast-Time Simulation Computer Model of an Automated Terminal Area Air Traffic Control System,** A. S. JACKSON, and R. V. MORSE, *Director of Research, Control Technology Inc., 1232 Belmont Avenue, Long Beach 4, California.*

4Wa. 2. **Experience with an Urban Renewal Decision Simulation Model,** WILBUR A. STEGER, *Systems Research and Planning, Consad Research Corp., 3406 Fifth Ave., Suite 301, Pittsburgh, Pennsylvania 15213.*

4Wa. 3. **A General Purpose Simulation Technique for Modeling Military Operations,** MARVIN KORNBLUH, REINO A. MERIKALLIO and JAMES E. O'HARA, *Washington Systems Center, IBM Corp., 7900 Wisconsin Avenue, Bethesda, Maryland.*

4Wa. 4. **An Introduction to C.S.L.,** DR. J. G. LASKI and J. N. BUXTON, *Corporate Planning Department, Esso Petroleum Co. Ltd., Victoria Street, London, S.W. 1, England.*

WEDNESDAY AFTERNOON, MAY 27

Session 4Wb. 3:45–5:15 p.m.

Real Time Control Systems (Continued)

Chairman: BEN BERNHOLTZ, *University of Toronto*

4Wb. 1. **Clustering of Defectives in Time,** JOSEPH I. NAUS, *Institute of Naval Studies, Center for Naval Analyses of the Franklin Institute, 545 Technology Square, Cambridge 39, Massachusetts.*

4Wb. 2. **Redetermination of Favourable Conditions in Chemical Reactions,** GEOFFREY L. COCKHILL, *Chemcell (1963) Limited, Montreal, P.Q.*

WEDNESDAY AFTERNOON, MAY 27

Session 4Wc. 3:45–5:15 p.m.

Satellites

Chairman: E. L. Leese, *R.C.A.F. Headquarters, Ottawa, Ontario*

4Wc. 1. **System Evaluation Techniques Applied to the Design of a Satellite Communication System,** Stanley Hauer, *Aerospace Group, Hughes Aircraft Co., Mobile Mid-Range Ballistic Missile Division, P.O. Box 90515, Los Angeles 9, California.*

4Wc. 2. **Utility of Partially Failed Communications Satellites as a Reserve,** Frank D. Mason, *Building 366, Mail Station 822-B, Hughes Aircraft Company, Culver City, California.*

4Wc. 3. **Scheduling in a Multiple Satellite Environment,** Robert A. Totschek, *System Development Corp., 2500 Colorado Avenue, Santa Monica, California.*

4Wc. 4. **Approximations for Satellite Distributions,** Richard F. Link, *Statistical Techniques Research Group, Princeton University, 167 Nassau Street, Princeton, New Jersey.*

WEDNESDAY AFTERNOON, MAY 27

Session 4Wd. 3:45–5:15 p.m.

Transportation Science Section of ORSA (Continued)

Chairman: Walter Helly, *The Port of New York Authority*

* 4Wd. 1. **The Action Point of Driver-Vehicle System,** E. P. Todosiev, *The Ohio State University, Department of Electrical Engineering, 2024 Neil Avenue, Columbus 10, Ohio.*

* 4Wd. 2. **Optimum Control of a System of Oversaturated Intersections,** Denos C. Gazis, *IBM Watson Research Center, P.O. Box 218, Yorktown Heights, New York.*

4Wd. 3. **Transportation Science Section of ORSA Business Session,** *Chairman:* Robert Herman, Research Laboratories, General Motors Corporation, Michigan.

WEDNESDAY AFTERNOON, MAY 27

Session 4We. 3:45–5:15 p.m.

Chairman: Walter E. Cushen, *Institute of Defense Analysis*

4We. 0. National Cost Effectiveness Analysis—Work Session (Continued)

WEDNESDAY AFTERNOON, MAY 27

Session 5Wb. 5:15–5:30 p.m.

Chairman: Alexander M. Mood, *President of ORSA*

Operations Research Society of America—Business Meeting

WEDNESDAY EVENING, MAY 27

6:00–8:00 p.m.

Cheese and Wine Tasting Party

Salle Helène de Champlain, St. Helen's Island

THURSDAY MORNING, MAY 28

Session 1Ta. 9:00–10:30 a.m.

Military Cost Analysis

Chairman: DAVID NOVICK, *The RAND Corporation*

* **1Ta. 1. Role of Cost in Military Decisionmaking,** WILLIAM A. NISKANEN, *Director, Special Studies, Office of the Assistant (Comptroller), Department of Defense.*

Discussants:

M. W. HOAG, *Economics Department, The RAND Corporation*
JOSEPH A. KERSHAE, *Provost, Williams College*
G. G. STEELE, *Assistant Deputy Minister of Finance and Secretary of the Treasury Board, Ottawa*

THURSDAY MORNING, MAY 28

Session 1Tb. 9:00–10:30 a.m.

*The Practice of Operations Research

Chairman: DR. HUGH MISER, *The Mitre Corporation*

Panelists:

T. E. CAYWOOD, *Peat, Marwick, Caywood, Schiller and Company*
EMORY COOK, *Operations Research Incorporated*
JOHN F. MAGEE, *Arthur D. Little Incorporated*
PATRICK J. ROBINSON, *Marketing Sciences Institute*

THURSDAY MORNING, MAY 28

Session 1Tc. 9:00–10:30 a.m.

Mathematical Programming

Chairman: PETER SANDOR, *J. Kates & Associates,*
"A Division of KCS Ltd"

1Tc. 1. On Round-Off Errors in Linear Programming, HEINER MULLER-MERBACH, *University of California, Operations Research Center, Richmond Field Station, 1301 South 46th Street, Richmond, California.*

1Tc. 2. Location-Allocation Problems in the ℓ_1-metric, A. CHARNES. J. E. QUON, AND S. J. WERSAN, *Northwestern University, Evanston, Illinois.*

1Tc. 3. Maximizing the Information Value of a Linear Programming Model, DONALD W. JOHNSON, *Vitro Laboratories, 14000 Georgia Ave., Silver Spring, Maryland.*

THURSDAY MORNING, MAY 28

Session 1Td. 9:00–10:30 a.m.

Transportation Science Section of ORSA

Chairman: DAVID EVANS, *General Motors Corporation*

* 1Td. 1. **Gap Acceptance Probabilities,** DONALD P. GAVER, *Carnegie Institute of Technology, Pittsburgh, Pennsylvania.*

* 1Td. 2. **Gap Availability and Acceptance at a Left Side and Right Side on Ramp,** ADOLPH D. MAY, JR. *State of Illinois Department of Public Works and Buildings, Division of Highways, 160 North La Salle Street, Chicago 1, Illinois.*

* 1Td. 3. **Stochastic Traffic Systems Whose Service Times Increase with Occupancy,** WALTER HELLY, *The Port of New York Authority, 111 Eighth Avenue, New York, N. Y.*

* 1Td. 4. **Maintenance of Commuter Train Schedule,** G. F. NEWELL, and R. B. POTTS, *University of Adelaide, South Australia.*

THURSDAY MORNING, MAY 28

COFFEE BREAK: 10:30–10:45 a.m.

Courtesy of: *International Business Machines Co. Ltd.*

THURSDAY MORNING, MAY 28

Session 2Ta. 10:45–12:15 p.m.

Military Cost Analysis (Continued)

Chairman: DAVID NOVICK, *The RAND Corporation*

* 2Ta. 1. **Concepts of Resource Analysis,** MAJOR GENERAL ROBERT J. FRIEDMAN, *Director of Aerospace Programs, Office of the Deputy Chief of Staff, Programs and Requirements, Headquarters, U. S. Air Force.*

* 2Ta. 2. **The Use of Cost Analysis in the U.S. Navy,** CAPTAIN EVAN P. AURAND, *Office of the Chief of Naval Operations.*

Discussants for the two papers:

I. C. CORNBLAT, *Canadair Services (Air Vice Marshal, RCAF, Ret.)*
P. W. CHERINGTON and JAMES J. HILL, *Graduate School of Business Administration, Harvard University.*
JOHN R. WALTER, *Stevenson and Kellogg Limited, Toronto.*

THURSDAY MORNING, MAY 28

Session 2Tb. 10:45–12:15 p.m.

The Practice of Operations Research (Continued)

Chairman: DR. HUGH MISER, *The Mitre Corporation*

THURSDAY MORNING, MAY 28

Session 2Tc. 10:45–12:15 p.m.

Mathematical Programming (Continued)

Chairman: PETER SANDOR, *J. Kates & Associates, "A Division of KCS Ltd"*

2Tc. 1. Methods for the Solution of Fractional Linear Programming Problems, H. C. JOKSCH, *The Mitre Corporation, Box 208, Bedford, Massachusetts.*

2Tc. 2. The Menu Problem, JOSEPH L. BALINTFY, DR. *Eng., Associate Professor of Operations Research, School of Business Administration, Tulane University, New Orleans.*

2Tc. 3. Schedule-Sequencing Problems, HENRI L. BEENHAKKER, *Stanford Research Institute, Menlo Park, California.*

THURSDAY MORNING, MAY 28

Session 2Td. 10:45–12:15 p.m.

Transportation Science Section of ORSA (Continued)

Chairman: DAVID EVANS, *General Motors Corporation*

* **2Td. 1. Two Problems in Scheduling Manpower,** A. M. LEE and R. W. LINDER, *Trans-Canada Air Lines, Place Ville Marie, Montreal, P.Q.*

* **2Td. 2. Optimizing Performance in an Automatic Freight Car Classification Yard—An Interim Approach,** C. E. LAW, D. C. LACH and G. V. JACQUEMAIN, *Canadian National Railways, Department of Research & Development, P.O. Box 8100, Montreal, P.Q.*

* **2Td. 3. Simulation Models of Railway Terminal Operations,** FREDERICK A. KOOMANOFF, *Department of Engineering Physics, Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio.*

THURSDAY AFTERNOON

Session 3Ta. 2:00–3:30 p.m.

Military Cost Analysis (Continued)

Chairman: John R. Walter, *Stevenson & Kellogg*

3Ta. 1. **Generalized Cost Models for Very Large Programs National Space Program Application,** Dr. George W. Morgenthaler, George Fosdick and Dr. R. S. Novosad, *Martin Company, Denver Division, Denver 1, Colorado.*

3Ta. 2. **Stochastic Nature of Military Cost Analysis,** Alfred G. Aswad, *Douglas Aircraft Co. Inc., Santa Monica, California.*

3Ta. 3. **Military Cost Effectiveness of Advanced Manned Aircraft Systems,** William E. Dickison and Roderic M. Dixon, *Systems Engineering Group, Research and Technology Division, Airforce Systems Command, United States Air Force, Wright-Patterson Air Force Base, Ohio 45433.*

THURSDAY AFTERNOON, MAY 28

Session 3Tb. 2:00–3:30 p.m.

*Mathematical Biology and Operations Research

Chairman: Dr. E. W. Paxson, *The Rand Corporation*

Panelists:

Professor George Dantzig, *University of California*
Dr. Robert Kalaba, *The Rand Corporation*
Dr. James Miller, *Mental Health Research Institute, University of Michigan*
Professor Peter Milner, *McGill University*
Dr. Oliver Selfridge, *Massachusetts Institute of Technology*

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THURSDAY AFTERNOON, MAY 28

Session 3Tc. 2:00–3:30 p.m.

Mathematical Programming (Continued)

Chairman: DR. HYMAN KAUFMAN, *Mathematics Department, McGill University*

3Tc. 1. Network Algorithm for the Traveling Salesman Problem, JOHN W. SUURBALLE, *Bell Telephone Laboratories Inc., Murray Hill, New Jersey.*

3Tc. 2. The Sequential Unconstrained Minimization Method for Nonlinear Programming, ANTHONY V. FIACCO, and GARTH P. MCCORMICK, *Research Analysis Corporation, McLean, Virginia 22101.*

3Tc. 3. A Stochastic Personnel-Assignment Model, WILLIAM R. KING, *Operations Research Group, Case Institute of Technology, Division of Organizational Sciences, University Circle, Cleveland 6, Ohio.*

THURSDAY AFTERNOON, MAY 28

Session 3Td. 2:00–3:30 p.m.

Transportation

Chairman: JOHN GRATWICK, *Canadian National Railways*

3Td. 1. Adjustment of Regional Boundaries to Keep the Contained Workload within a Prescribed Tolerance, J. C. CLAPHAM, *Head—Operations Research Section, British Columbia Research Council, University of British Columbia, Vancouver 8, B.C.*

3Td. 2. Vehicular Traffic Control—A Time-Space Design Model, L. A. YARDENI, *IBM Corporation, General Products Division Development Laboratory, Monterey & Cottle Roads, San José 14, California.*

3Td. 3. Optimal Selection of Commercial Aircraft, GRAHAM D. CLAPP, *Operations Research Group, Case Institute of Technology, University Circle, Cleveland 6, Ohio.*

THURSDAY AFTERNOON, MAY 28

BREAK: 3:30–3:45 p.m.

THURSDAY AFTERNOON, MAY 28

Session 4Ta. 3:45–5:15 p.m.

Military Cost Analysis (Continued)

Chairman: John R. Walter, *Stevenson & Kellogg*

4Ta. 1. **Logistics Cost and Effectiveness,** R. L. Weiss, *Manager Advanced Logistics, Space and Information Systems Division, North American Aviation, Inc., 12214 Lakewood Boulevard, Downey, California.*

4Ta. 2. **Assignment of Errors to Aerospace Cost Equations,** Peter J. Crumbine, *Manager Cost Effectiveness Evaluation, Lockheed Missiles & Space Co., Sunnyvale, California*

4Ta. 3. **Evaluation of Complete System Costing,** Theodore Bullockus, *Executive Advisor, Douglas Aircraft Co. Inc., Long Beach, California.*

4Ta. 4. **Common Proposal Strategies for Both Military and Commercial Opportunities,** John H. Tinley, *Advanced Plans Engineering and Product Development, Aircraft Division, Douglas Aircraft Company.*

THURSDAY AFTERNOON, MAY 28

Session 4Tb. 3:45–5:15 p.m.

Mathematical Biology and Operations Research (Continued)

Chairman: Dr. E. W. Paxson, *The Rand Corporation*

THURSDAY AFTERNOON, MAY 28

Session 4Tc. 3:45–5:15 p.m.

Mathematical Programming (Continued)

Chairman: Dr. Hyman Kaufman, *Mathematics Department, McGill University*

4Tc. 1. **Sensitivity Analysis of Multi-terminal Flow Networks,** Salah E. Elmaghraby, *Associate Professor, Department of Industrial Administration, Yale University, New Haven, Connecticut.*

4Tc. 2. **On Some Numerical Difficulties Associated with Dynamic Programming,** G. S. Tracz, *Department of Industrial Engineering, University of Toronto, Toronto 5, Ontario.*

4Tc. 3. **Optimum Design of Open Pit Mines,** H. Lerchs, F. I. Grossmann, *International Business Machines Co., 615 Dorchester Boulevard, Montreal 2, P.Q.*

THURSDAY AFTERNOON, MAY 28

Session 4Td. 3:45–5:15 p.m.

Transportation (Continued)

Chairman: JOHN GRATWICK, *Canadian National Railways*

4Td. 1. **A Queueing Approach to Traffic Light Phasing,** P. ROBILLARD and PAUL NAOR, *Department of Statistics, University of North Carolina, Chapel Hill, North Carolina.*

4Td. 2. **Synchronizing Traffic Signals for Maximum Bandwidth,** JOHN D. C. LITTLE, *School For Industrial Management, M.I.T., Cambridge, Massachusetts, and* JOHN T. MORGAN, *Department of Statistics, Australian National University, Canberra, A.C.T., Australia.*

4Td. 3. **Some Quantitative Findings of Simulated Traffic Congestion,** HANS G. VON CUBE, *Traffic Research Corporation Limited, 20 Spadina Road, Toronto 4, Ontario.*

4Td. 4. **Simulation of a Transportation System Operating Different Fleets of Vehicles,** M. STADE, *Senior Engineer, Department 839, Canadair Limited, P.O. Box 6087, St. Laurent, Montreal, P.Q.*

THURSDAY EVENING, MAY 28

RECEPTION: 6:00 p.m.

THURSDAY EVENING, MAY 28

BANQUET: 7:00 p.m.

Speaker: DR. O. M. SOLANDT, O.B.E., M.A., M.D., LL.D., F.R.S.

"Soviet Research"

DR. SOLANDT, *the founding president of the Canadian Operational Research Society, will have recently returned from a trip to Russia as a guest of the Soviet Union. He will describe the highlights of his trip and analyze the progress of Russian research and its relation to Operation Research.*

FRIDAY MORNING, MAY 29

Session 1Fa. 9:00–10:30 a.m.

Case Histories

Chairman: K. J. RADFORD, *Defense Research Board*

1Fa. 1. An Application of Operations Research to Municipal Planning: Some Fiscal Aspects of Land Use Planning, MAJOR M. J. AGNEW, *Hq. USAF, Washington, D. C. and* CAPTAIN M. H. ALEXANDER, *Hq. AFSC, Andrews AFB, Md.*

* **1Fa. 2. Operational Research in the Scheduling of Fertilizer Production at COMINCO,** J. E. ROBERTS, *Research and Development Division, The Consolidated Mining and Smelting Company of Canada Ltd.*

1Fa. 3. Optimum Safety Stock in a Coal-Ordering Problem, D. K. A. GILLIES, J. G. C. TEMPLETON, and W. H. WINTER, *Operations Research Group, The Hydro-Electric Power Commission of Ontario, 200 Kipling Ave. South, Toronto 18, Ontario.*

FRIDAY MORNING, MAY 29

Session 1Fb. 9:00–10:30 a.m.

Strategy of Information Retrieval

Chairman: MARTIN L. ERNST, *Arthur D. Little, Inc.*

* **1Fb. 1. Requirements of Users of Scientific and Technical Information,** CHARLES M. STEARNS, *Office of Technical Services, Department of Commerce, Washington, D. C.*

* **1Fb. 2. Information Retrieval Problems in the U. S. Patent Office,** EZRA GLASER, *Assistant Commissioner, U. S. Patent Office, Washington 25, D. C.*

FRIDAY MORNING, MAY 29

Session 1Fc. 9:00–10:30 a.m.

Queueing

Chairman: Dr. Jacques St-Pierre, *Professor of Statistics, Univèrsité de Montréal*

1Fc. 1. **Queueing in Series-Parallel Networks,** Henry D. Friedman, *Applied Research Laboratory, Sylvania Electronic Systems, 40 Sylvan Road, Waltham 54, Massachusetts.*

1Fc. 2. **Multi-Channel Queueing with Periodic Service Interruptions,** John J. Coleman, and T. P. Giammo, *Space Technology Laboratories, Thompson Ramo Wooldridge, One Space Park, Redondo Beach, California.*

1Fc. 3. **Tandem Queues with Dynamic Priorities,** Andrew Grindlay, *Assistant Professor, University of Western Ontario, School of Business, Administration, London, Ontario.*

FRIDAY MORNING, MAY 29

Session 1Fd. 9:00–10:30 a.m.

Military O.R.

Chairman: David M. Homa, *Demers, Homa, Baby, Consulting Engineers*

1Fd. 1. **Adaptation of an Existing Naval Proximity Fuse to Supersonic Targets,** R. D. Wilmot, *1386 Gibson Avenue, Ottawa, Ontario.*

1Fd. 2. **Some Comments on the Lanchester Theory of Combat,** R. M. Durstine, *The Mitre Corporation, Bedford, Massachusetts.*

1Fd. 3. **The Distribution of Rounds Fired in Stochastic Duels,** Clinton J. Ancker Jr. and A. V. Gafarian, *System Development Corporation, 2500 Colorado Avenue, Santa Monica, California.*

1Fd. 3′. **Some Discrete Processes in the Theory of Stochastic Duels,** C. J. Ancker, Jr., *System Development Corporation, 2500 Colorado Ave., Santa Monica, California, and* Trevor Williams, *The Johns Hopkins University, Baltimore, Maryland.*

1Fd. 4. **Operations Research Techniques in Radiological Civil Defense,** F. Lemus and J. T. Ryan, *Operations Analyst, Research Triangle Institute, P.O. Box 490, Durham, North Carolina.*

FRIDAY MORNING, MAY 29

COFFEE BREAK: 10:30–10:45 a.m.

Courtesy of: *Remington Rand, Univac Division.*

FRIDAY MORNING, MAY 29

Session 2Fa. 10:45–12:15 a.m.

Case Histories (Continued)

Chairman: K. J. RADFORD, *Defense Research Board*

2Fa. 1. Maintenance Planning for the Minuteman Weapon System, R. R. CALDWELL and R. A. CAWBY, *The Boeing Company, Seattle, Washington*

* **2Fa. 2. Scheduling of Preventive Maintenance on the Mid-Canada Line,** T. A. EWASHKO and R. L. BAGLOW

* **2Fa. 3. An Operational Research Study of the Determination and Prediction of Satellite Orbits,** E. C. KEHAYAS, *H. S. Gellman and Co. Ltd., Toronto, Ontario and J. L. Hudson, Directorate of Systems Evaluation, R.C.A.F., Ottawa, Ontario.*

FRIDAY MORNING, MAY 29

Session 2Fb. 10:45–12:15 a.m.

Strategy of Information Retrieval (Continued)

Chairman: MARTIN L. ERNST, *Arthur D. Little, Inc.*

* **2Fb. 1. Techniques for Associative Information Retrieval,** VINCENT E. GIULIANO, *Operations Research Section, Arthur D. Little, Inc., 35 Acorn Park, Cambridge 40, Massachusetts.*

* **2Fb. 2. Man-Machine Interaction in Information Retrieval,** CHARLES W. ADAMS, *President, Charles W. Adams Associates Inc., Bedford, Massachusetts.*

FRIDAY MORNING, MAY 29

Session 2Fc. 10:45–12:15 p.m.

Queueing (Continued)

Chairman: DR. JACQUES ST-PIERRE, *Professor of Statistics, Univèrsité de Montréal*

2Fc. 1. A Queueing System with Alternating Priority, B. AVI-ITZHAK, TECHNION, *Israel Institute of Technology, Israel and* W. L. MAXWELL, and L. W. MILLER *of Cornell University, Ithaca, New York.*

2Fc. 2. On Jockeying in Queues, ERNEST KOENIGSBERG, *C-E-I-R, Inc., 345 Howard Street, P.O. Box 3243, San Francisco.*

2Fc. 3. Markov Chain Analysis of a Sorting Machine: Formulae and Illustrative Applications, JOEL LEVY, *National Bureau of Standards, Room 140, North Building, Washington 25, D. C.*

FRIDAY MORNING, MAY 29

Session 2Fd. 10:45–12:15 p.m.

Planning

Chairman: ELIZABETH RABITSCH, *Chemcell (1963)* Limited

2Fd. 1. Fatefulness: A Measure Deserving Recognition, JOHN COYLE, *4706 North 36th Street, Arlington 7, Virginia.*

2Fd. 2. Forecasting: A Pitfall in Military and Civilian Long Range Planning, HAROLD A. LINSTONE, *Senior Scientific Advisor, Corporate Development Planning, Lockheed Aircraft Corporation, Burbank, California.*

2Fd. 3. Concepts for Mission and System Planning, NORMAN HITCHMAN, *Technical Military Planning Operation, General Electric Company, 735 State Street, Santa Barbara, California.*

FRIDAY AFTERNOON, MAY 29

LUNCHEON 12:30 p.m.

ORSA Presidential Address

Speaker: Alexander M. Mood, *Operations Research Society of America*
Chairman: Gordon D. Shellard

FRIDAY AFTERNOON, MAY 29

Session 3Fa. 2:00–3:30 p.m.

Special Topics

Chairman: Peter F. Wade, *Price Waterhouse & Company*

3Fa. 1. Strategies of Speculation in the Stock Market, J. T. Ross Jackson, *Operations Research Group, Case Institute of Technology, Department of Management, University Circle, Cleveland 6, Ohio.*

3Fa. 2. Stock Exchange Volume as a Stochastic Process, Harold Greenberg and Irwin Greenberg, *College of Engineering, New York University, Department of Industrial Engineering and Operations Research, New York University, New York 53, N. Y.*

3Fa. 3. Implementation of Operational Research—A Problem in Sociology, John W. Abrams, *Department of Industrial Engineering, University of Toronto, Toronto 5, Ontario.*

FRIDAY AFTERNOON, MAY 29

Session 3Fb. 2:00–3:30 p.m.

Information Retrieval

Chairman: H. J. G. Whitton, *Trans Canada Air Lines*

3Fb. 1. New Dimensions in Information Retrieval Systems, Henri L. Beenhakker, *Stanford Research Institute, Menlo Park, California.*

3Fb. 2. A Computer-Generated Thesaurus, P. B. Henderson Jr., *Advanced Data Systems, Westinghouse Electric Corp, 15 West 3 Gateway Center, Box 2278, Pittsburgh 30, Pennsylvania.*

3Fb. 3. Dial-A-Document Central Libraries, William L. Alden, *President, Automation Management Inc., Westboro, Massachusetts.*

FRIDAY AFTERNOON, MAY 29

Session 3Fc. 2:00–3:30 p.m.

Systems

Chairman: CHARLES JONES-WHITTEY, *Northern Electric Co. Ltd.*

3Fc. 1. The Integration of Human and Machine Performance, ERIK A. R. HALDANE, *3327 "N" Street, N.W. Washington D. C. 20007.*

3Fc. 2. Control Theory in Nonstationary Ecosystems, MARK ALFANDARY-ALEXANDER, *University of Pittsburgh, Visiting Professor, Research Analysis Corp., 6935 Arlington Road, Bethesda 14, Maryland.*

3Fc. 3. Towards a General Theory of Systems-Models of Subsystems, FRANK BENSON and MEHMET GUREL, *Case Institute of Technology, Cleveland Ohio.*

FRIDAY AFTERNOON, MAY 29

Session 3Fd. 2:00–3:30 p.m.

Planning (Continued)

Chairman: ELIZABETH RABITSCH, *Chemcell (1963) Limited*

3Fd. 1. Cost Benefit Analysis and Project Evaluation, JOHN S. MACDONALD, *Room 2731, United Yations, Box 20, Grand Central P.O., New York, N. Y.*

3Fd. 2. Planning, JACQUELINE ANDERSON, *Operations Research Group, Case Institute of Technology, University Circle, Cleveland 6, Ohio.*

3Fd. 3. An Heuristic Approach to Corporate Planning by Aggregating Models of Business Functions, MARK E. STERN, and BERNARD B. HANON, *New York University, Graduate School of Business Administration, 100 Trinity Place, New York 6, N. Y.*

FIRDAY AFTERNOON, MAY 29

BREAK: 3:30–3:45 p.m.

FRIDAY AFTERNOON, MAY 29

Session 4Fa. 3:45–5:15 p.m.

CORS Business Session

Chairman: A. PORTER

FRIDAY AFTERNOON, MAY 29

Session 4Fc. 3:45–5:15 p.m.

Decision

Chairman: Charles Jones-Whittey, *Northern Electric Co. Ltd.*

4Fc. 1. Model for Decision—A Method for Selecting R & D Efforts, Melvin Tanchel, *Technical Advisor, Directorate of Technology, Hq. AFSC, United States Air Force, Andrews Air Force Base, Washington 25, D. C.*

4Fc. 2. A New Weight-Setting Model for General Use in Evaluations, Leroy R. Rosen, *Department of the Navy, Bureau of Ships, Washington 25, D. C.*

4Fc. 3. POED—A Method of Evaluating System Performance, D. R. J. White and D. L. Scott, *White Electromagnetics Inc., 670 Lofstrand Lane, Rockville, Maryland.*

FRIDAY AFTERNOON, MAY 29

Session 4Fd. 3:45–5:15 p.m.

Planning (Continued)

Chairman: C. E. Law, *Canadian National Railways*

4Fd. 1. Allocating Restricted Resources to a Project Network, Dr. R. L. Martino, *Manager, Advanced Systems, Olin, 460 Park Avenue, New York 22, N. Y.*

4Fd. 2. On Expected Times for PERT Activities, Klaus Abt, *U. S. Naval Weapons Laboratory, Dahlgren, Virginia.*

Abstracts

2Wa. 2. The Statistical Properties of Large Battle Simulations, Franklin C. Brooks, *Technical Operations Inc., South Avenue, Burlington, Massachusetts.*

This paper considers stochastic simulations of large battles, such as STAGE (Simulation of Total Atomic Global Exchange). Cf. Pennington, Abstract N-2, *Opns. Res. 11*, Supplement 1 (Spring 1963) and Adams and Jenkins, *Opns. Res. 8*, 600–615 (1960). Such battle models are said to be stochastically determined if the gross results, for example the casualties to each side, show low variance in repeated plays in which only the random numbers are changed. Here, low variance means a standard deviation small compared to the initial number of weapons engaged. When stochastic determinism exists in a large battle model only a few replications of the model are needed to get good estimates of the gross results. Stochastic determinism with respect to casualties is shown to be present when the correlations between losses of individual weapons are relatively small or few in number, that is when the fate of a given weapon has strong influence on the fates of only a limited number of other weapons. Three stochastic models—the Lanchester Linear and Square Law models and a simple missile battle model—which can be studied analytically are shown to be stochastically determined. Features of battle models which would lead to violation of stochastic determinism are discussed.

2Wa. 3. COMMAND: A Model of a Network of Command Systems, R. M. Longmire, *Development Division, System Development Corporation, 2500 Colorado Avenue, Santa Monica, California.*

This paper summarizes the functional design of COMMAND (COMmand Model for ANalysis and Design) and discusses possible applications of the model to the study of command system problems.

COMMAND simulates aspects of the operation of a network of command systems opposing a rudimentary enemy command network prior to, and during a general nuclear war. The model consists of four major components: Adaptive Scenario, Engagement Analyzer, Situation Recognizer, Action Selector. The Adaptive Scenario simulates the enemy command operations and provides status reports on hypothetical US commands and other countries which are referred to in the model but are not simulated. The Engagement Analyzer provides a simulated natural environment where in the resources of each opposing side can react with one another and with nature, in accordance with carefully determined relationships. Tactical intelligence data processing and estimating operations of friendly commands are simulated by the Situation Recognizer. The Action Selector represents the force management functions which are performed by the organization of friendly commands. COMMAND has been designed so that it can be implemented as a modular computer program system, providing the means for using different combinations of its four basic components in both open and closed simulation, i.e. with and without people. The computer programs have been coded in JOVIAL and are now being tested for operation in the time-sharing system of the AN/FSQ-32 computer in the System Development Corporation's Command Research Laboratory. This work was sponsored by the Advanced Research Projects Agency of the Department of Defense under contract SD-97.

2Wa. 4. Modeling and Simulation as a Research Tool, WARREN A. JOSLYN, *Systems Research, The Boeing Company, P.O. Box 3707, Seattle 24, Washington.*

Application of Modeling and Simulation to commercial and military problems can be determined by a set of rational considerations that lend themselves to evaluation. In this manner, any emotional associations with the use or non-use of this research tool can be overcome. A checklist of factors is presented including the study objectives, system characteristics, type, restraints, and desired results. These factors should be duly considered and evaluated in order that the decision to model or simulate may also incorporate the level of complexity or sophistication appropriate to the problem. Several types of simulation models are illustrated and discussed.

* **2Wb. 1. Centralized Traffic Control by Digital Computers,** DR. J. KATES, *Traffic Corporation Limited, 20 Spadina Road, Toronto, Ontario.*

For this talk the traffic problems of modern cities will at first be briefly reviewed and the following points will be discussed: The lack of scientific attack on the traffic problem until recently; the functions of transportation planning and traffic control; the control methods available to the traffic engineer; a brief history of traffic signals. At this stage in the discussion a ten minute colour sound movie will be shown which describes the recent experiment with computer control in Toronto. Then the plans for a very ambitious traffic control system will be discussed. This system is now becoming operational and progress of this system will be illustrated and discussed.

* **2Wb. 2. Real-Time Control on Interconnected Power Systems,** R. D. NEVISON, *Assistant Production Engineer, Operating Department Ontario Hydro.*

This paper traces the growth of electric power systems from their rudimentary beginning to the present vast interconnections and the concomitant evolution of control techniques needed to make these interconnections feasible. The principles and hardware required for the control of isolated systems and power interchange between systems forming large interconnections are described. The theory of loading resources on power systems for best economy and the application of digital computers to effect this economic loading are presented. Also presented are the reasons for the growth of interconnections and a brief description of the multi-system interconnection presently embracing Ontario-Quebec and most of the United States.

2Wc. 1. On a Mixed-Sequential Estimating Procedure with Application to Audit Tests in Accounting, A. CHARNES, *Northwestern University, Re-*

search Professor of Applied Mathematics and Economics, Evanston, Illinois; H. JUSTIN DAVIDSON, *Touche, Ross, Bailey and Smart;* K. KORTANEK, *Northwestern University and University of Chicago.*

In the commonplace audit situation of developing a valid opinion on the state of control of a business system, the use of various statistical sampling techniques has been long advocated. In this control evaluation circumstance we state the sampling objective as discovering as rapidly as possible whether particular error rates are in an acceptable range and, if not, estimating with prescribed assurance what the error rates might be. The new statistical model we propose involves the combination of sequential and fixed sample size procedures since they are, respectively, most efficient for testing an acceptability hypothesis or determining a confidence interval. The resulting mixed procedure, in contrast to others in the literature, begins with the sequential part (since most of the time acceptance is to be anticipated) and continues to a priori fixed total in the event of non-acceptance. Thus the procedure yields one of two final conclusions, either to accept the prescribed hypothesis or provide a confidence interval estimate of the unknown error rate. From a practical viewpoint it is possible to reduce the seemingly numerous specifications which are necessary for mixed-procedures. In short, while additional computation is required to determine optimum parameter values, the basic specifications are similar to those required for the classic procedures of estimating an unknown parameter.

2Wc. 2. Bayesian Operations Research, LOCKWOOD RIANHARD, JR., *Assistant Professor, State University of New York at Buffalo, Crosby Hall, Library Circle, Buffalo 14, New York.*

Traditional operational research and econometric methods for decision making are contrasted with methods based upon the Bayesian concept that an unknown model parameter should be treated as a random variable unless the substitution of a certainty equivalent can be justified. A simple inventory situation is used to illustrate the traditional procedure and the Bayesian procedure. Decision situations traditionally formulated as mathematical programming problems under certainty are shown to have Bayesian formulation as stochastic programming problems.

2Wc. 3. On the Principle of Maximizing Entropy, DONALD J. CLOUGH' *Department of Industrial Engineering, University of Toronto, Toronto 5, Ontario.*

In recent years engineers, physicists, and some operations researchers have shown interest in the "principle of maximizing entropy" as a basis for making decisions in the face of uncertainty. The principle of maximizing entropy is nothing more than an extension of Laplace's principle of insufficient reason. However, it has been dressed in such a formalism of mathematical approach, irrational argument, and jargon about "information" and "subjective probability" that its essential nature has become obscured. Many misconceptions have evidently arisen out of the belief that a procedure which has been applied successfully in the field of small-particle mechanics, for example, should have utility in any other field.

There is in fact no generally acceptable evidence to support such a belief. It is the purpose of this paper, (1) to define entropy in the conventional terms of probability theory, simply as a parameter of a probability distribution, (2) to show that the use of the principle of maximizing entropy amounts to the arbitrary choice of the mathematical form of an unknown probability distribution, that which has the largest entropy parameter subject to constraints imposed by fixing one or more of its other parameters (such as moments, ranges, and quantiles), and (3) to discuss certain implications of the use of the principle and its relationship to information theory.

2Wc. 4. Independence in Utility Theory, PETER C. FISHBURN, *Research Analysis Corporation, McLean, Virginia, 6935 Arlington Road, Bethesda 14, Maryland.*

It is assumed that a von Neumann-Morgenstern type utility function φ exists on a set X of ordered n-tuples $(x_1, x_2, \cdots, x_n)$ with $X \subset X_1 x X_2 x \cdots x X_n$. φ is unique up to a positive linear transformation, $a\varphi + b$ with $a > 0$. In this paper necessary and sufficient conditions for φ to have the form $\varphi(x_1, x_2, \cdots, x_n) = \varphi_1(x_1) + \varphi_2(x_2) + \cdots + \varphi_n(x_n)$ are developed starting with $n = 2$, and a necessary and sufficient condition on X is given in order that $\varphi_1, \varphi_2, \cdots, \varphi_n$ be unique up to a set of simultaneous positive linear transformations with common scale multiplier $a > 0$. The development is free of any specific assumptions about φ (e.g., continuity, differentiality, etc.) except for its uniqueness up to a positive linear transformation.

*** 2Wd. 1. Survey of Operations Research in Textiles,** JACK B. COURSEY, *Operations Research Analyst, Research Triangle Institute, Durham, North Carolina.*

A compendium of applied Operations Research techniques will be presented which will indicate both methods and problem areas within the textile industry. The textile industry is one of the most important industries in the United States. The problems besetting the textile industry extend from highly complicated technical problems (*e.g.* chemistry and technology) to basic management problems (*e.g.* personnel and allocation of funds). It is also a most competitive industry. The largest textile company represents less than 7 percent of the total sales of the industry, and there are over 7,500 companies. Operations Research has been used successfully in textiles. Among the applied Operations Research topics have been inventory control, PERT, Monte Carlo, linear programming and others. Examples of these and others will be given with particular emphasis on the application of linear programming in textiles.

*** 2Wd. 2. Product Line Strategy in Style Merchandising,** KURT H. SCHAFFIR, *Arthur Andersen & Co., 80 Pine Street, New York 5, N. Y.*

Manufacturers of textiles, garments and similar style merchandise are faced each season with a series of decisions involving the number of different lines and varieties to be offered for sale, the amount of initial stock to be provided for each variety, and the manner in which available production capacity is to be allocated among these different lines and varieties as the season progresses. These decisions require that a proper balance be found between initial stock and reorder production. The present paper explores the economic factors by which this proper balance is determined.

* 2Wd. 3. Flow Analysis of Variations with Applications to Textile and Other Industries, DR. NORBERT LLOYD ENRICK, *University of Virginia, Charlottesville, Virginia.*

In many instances in the past, applications of new techniques originated for the textile industry, have subsequently found wider usage in industry as a whole. Examples are punched cards for storage of information and instructions, the use of ratio-delay work sampling, and automation. Flow Analysis of Variations is a minor example. Developed for tracing the flow of variances, within-machines, between-machines and departmental-overall, from process to process, in multi-machine multi-output situations in textile industries—and first applied in a Montreal textile mill—it is now in use in several hundred mills. Precise evaluation of the components of variations, and estimation of permissible variations flow from process to process, permits accurate diagnosis of trouble spots in production and their probable causes. Reduced variability, improved running conditions, and higher-precision results are thus accomplished. A textile and a foundry illustration will be given, both originating in the Province of Quebec.

* 2Wd. 4. How to Make Rough Models of Complex Systems, C. F. MILLER III, and D. S. MCARTHUR, *Deering Milliken Service Corporation, Spartanburg, South Carolina.*

Approximate mathematical models of complex systems are usually all that can be (practically) developed in industrial O.R. work. How should such models be made? This paper illustrates the development of such a model from a combination of theoretical and statistical considerations. A single yarn unraveled from a yard of woven fabric is more than a yard long. Just how much longer is important to the weaver. He needs to know how much yarn (and hence cost) must be supplied to make a yard of fabric. The problem is complex. No useful theoretical model of yarn take-up in weaving has been developed. The take-up along the length of the cloth is dependent on the take-up across the width. Both take-up factors depend on several cloth construction variables (such as the number of yarns and the yarn sizes) and on several manufacturing variables. This paper shows how a rough model reflecting take-up was developed for 3 cotton mills. It was based on some theoretical considerations supplemented by considerable data collected from the operating mills. The theoretical work provided some information on the "form" of the model and statistical regression analysis generated the useable model. The method appears to be generally useful on a large class of industrial problems.

3Wa. 1. A Relationship Between Decision Making Penalty and Simulation Sample Size, M. E. BRENNER, *Bell Telephone Laboratories, Inc., Holmdel, New Jersey.*

The paper contains some results from experiments in which two inventory models, whose analytical solutions are known, have been simulated in order to learn more about simulation. The author suggests a relationship between the sample size in the simulation and the economic penalty for an incorrect decision from inaccuracy in the simulated information. The form of relationship is $\bar{w} = A/n^k$, where $\bar{w}$ is the average penalty in dollars, n is the sample size, and A and k are parameters obtained from a regression analysis. A series of results are reported with values given for A and k. The values of A vary monotonically with some of the inventory parameters. The values of k have moderate variability. It is hoped that the ideas suggested and the results presented may be helpful to others conducting experiments to learn more about simulation.

3Wa. 2. Testing the Overall Sensitivity of the Mathematical Model,

J. C. NAPOLI, *Plans and Systems Analysis, Douglas Aircraft Company, Long Beach, California.*

Testing the overall sensitivity of the mathematical model is an important phase of any operations research study. Unfortunately, in many studies this phase is severely limited because of the tremendous number of combinations of parameter values that are possible. This paper presents a procedure which combines the simplicity of Monte Carlo analysis with the power of order statistics to draw inferences regarding the likelihood that the system will operate at prespecified levels. The method is particularly applicable to critical path networks and reliability models, which involve many parameters whose values are not known with certainty.

3Wa. 3. COG: Combinatorial Optimum Generating,

WINSTON RILEY III, *C-E-I-R, INC., 1200 Jefferson Davis Highway, Arlington, Virginia.*

The technique described in this paper for solving Operations Research models that are basically combinatorial employs an approach which is itself basically combinatorial. The concepts involved are presented generally, as well as results to date. Required in the first instance are procedures which, more than enumerate, *generate* sequentially complete sets of combinations (solutions) in specified orders. Such generators are governed in their functioning by parameters delimiting specified sub-sets of the combinations. Restrictions and constraints to the problem to be solved are introduced by the manipulation of these generator parameters. While (A) this assures that only valid alternative solutions to the problem will be generated, (B) more restrictive manipulation may eliminate the generation of "clearly unreasonable" solutions. All generated solutions are evaluated, according to the various objective criteria, and the best-to-date solutions maintained concurrently. Under conditions of only (A) above, the resultant solutions are fully optimum to the problem as formulated. If the combinatorial nature of the problem indicates that there exists a relatively large number of unreasonable, though valid, solutions, it may be required (perhaps just advisable) to impose various type (B) restrictions. The number and kind of delimiting parameters on the generator that are utilized will produce the degree of acceptability of the solution. Clearly, the economies of this technique depend upon the speed and coding efficiency of modern computing equipment as well as mathematical efficiency from analysis of combinatorial optimum generating. Further research in the latter area will produce the greatest advances for this technique. Two applications to which this technique has been applied (resource allocation and multi-project scheduling, and vehicle fleet routing) are discussed, and computational experience is presented.

* **3Wb. 1. Survey of Dynamic Optimization Techniques,** DR. MURRAY WONHAM, *Center for Control Theory, Research Institute for Advanced Studies, 7212 Bellona Ave., Baltimore 12, Maryland.*

This paper is a survey of current techniques for the optimization of control systems described by differential or difference equations. Methods based on the theories of Pontryagin and Bellman are illustrated by examples; and the extension of these methods to stochastic optimal control problems is outlined.

* **3Wb. 2. On-Line Process Control Computers and Operations Research,** T. M. STOUT, *TRW Computer Division, 8433 Fallbrook Avenue, Canoga Park, California.*

About 150 digital computers have been ordered or installed as on-line process control devices by petroleum, chemical, steel, cement, synthetic rubber and paper companies. These computers are directly connected to process instruments and, at a minimum, produce typewritten logs of basic measurements and computed quantities. Many of the computers are also connected to devices which permit adjustment of process conditions for greater production or better control of product quality. In this paper, system functions are clarified by several specific examples. A "Classical" approach to computer control system design includes definition of system objectives (such as maximum profit subject to quality and equipment constraints), development of a mathematical model of the process, and invention of an algorithm by which process conditions meeting the objectives can be calculated. Many processes have proved too complex for a direct application of this approach. Although it has generally been possible to develop adequate models, rigorous optimization calculations could not be performed in real time with the mathematical techniques available and a computer of reasonable cost. Happily, where the "classical" approach has been applied in practice, the profit objective has frequently degenerated to a number of subsidiary objectives expressed in strictly technical terms. Other simplifications have been possible. In addition, many systems have been designed from the outset as aggregations of independent subsystems, performing control functions that could be performed by conventional equipment but not as conveniently. In short, few of the operating computer control systems have employed comprehensive mathematical models or formal optimizing techniques such as linear or dynamic programming. Most of the design work has been done by process, control and instrument engineers. As more powerful computers and sharper mathematical tools become available, however, more ambitious projects are being attempted. Operations research people and techniques should both play a larger role in the future; some areas for work are discussed in the paper.

3Wc. 1. Minimax Solutions of Problems on Distributions of Search Effort, ALBERTO RAUL GALMARINO, *Associate Professor in Mathematics, Northeastern University, Room 418U, Boston 15, Massachusetts.*

The problem of optimum distribution of search effort, as treated by B. O. KOOPMAN (Opn. Res. 5, 613–626 (1957)) and by J. DE GUENIN (Opn. Res. 9, 1–7 (1961)), is modified as follows: A target is known to be located in a certain space S. A searcher has a known total amount of search effort available F, to distribute in S. The searcher and the target are assumed to play a zero-sum two-person game, where the pay-off function is the overall probability of detection of the target by the searcher. The set of strategies for the target are all probability distributions $g(x)$, $x \epsilon S$. The set of strategies for the searcher are all distributions $f(x)$, $x \epsilon S$, of the search effort F. The existence and properties of the minimax solutions depend on the space S and on the functional dependence $p(f(x), x)$ of the probability of detecting the target with an effort $f(x)$ when the target is at x. The minimax solutions are obtained and discussed under different assumptions on S and $p(f(x), x)$.

3Wc. 2. A General Antisubmarine Attack Model, DR. ALEX HERSHAFT, Operations Evaluations Group, *Center of Naval Analysis of the Franklin Institute, Navy Department, Washington 25, D.C.*

A general antisubmarine attack model is developed in order to study the effect of various parameters on the probability of placing a weapon within a given distance of the target. Whenever practical, the probability distribution functions are presented in analytical form; other computational techniques are suggested in the remaining cases. A broad spectrum of component errors and other factors which bear on the fire control solution are discussed, and wherever possible, this contribution to the final probability distribution expression is formulated. Among the topics considered are the errors in estimated range, bearing, course, and speed of the target, the delivery errors of the weapon, and the value of prediction of future target positions and of evasive maneuvers. The model is designed to offer the user maximum freedom of choice as to the tactical situation, tracking method, weapon system, etc. Throughout, the underlying concern is less with the derivation of a pat formula ready for insertion of parametric values than with providing the user with an operational framework and the tools required for an intelligent evaluation and formulation of solution components. About 60 recent publications on the subject were reviewed in the preparation of this model.

3Wc. 3. An Analysis of Re-entry Vehicle Defense Penetration, HAROLD C. SEBRING, Advanced Space Projects Department, *Room 7246-CCF #7, General Electric Company, P. O. Box 8661, Philadelphia 1, Pennsylvania.*

An analytical model is developed to study the re-entry vehicle-defense engagement. It is applicable to any three-dimensional re-entry pattern of decoys and R/V's. The problem is assumed to be concerned with six boundary states: (1) R/V detection range, (2) maximum R/V range at antimissile missile firing time, (3) decoy discrimination boundary, (4) maximum AMM range, (5) minimum R/V altitude at AMM firing time, and (6) minimum AMM burst altitude (dead zone boundary). The principal variables, such as AMM intercept rate, R/V re-entry rate, travel time in the attack zone, etc., are given a parametric analysis. Quantitative support is given to the utility to re-entering all objects with minimum time and trajectory spacings. Since the location of a decoy in the penetrating cloud may permit a gain in AMM firing time, it is concluded that randomly assigning decoy positions may not be the best strategy. The degree of order in the decoy position assignment depends on the ratio of available defense firing time prior to decoy discrimination to the available time thereafter.

3Wc. 4. Non-Heuristic Methodology for Determining Optimum Logistics Support for Manned Orbiting Space Laboratories, ROBERT F. BURNES, *Operations Research Assistant, Lockheed Aircraft Corporation, California Division, Burbank, California.*

Once a manned space station is successfully launched into orbit, it will be able to remain there only so long as it has supplies for both its crew and its own operation and functioning. Consequently, before any attempts is even made to launch a space station into orbit, the logistics requirements associated with the station must first be identified, investigated, and proven capable of being accomplished successfully. Such an approach is mandatory to insure compatibility between the ground support and space station systems, in any space station program. In accomplishing this task, a methodology is developed whereby pertinent logistics parameters are identified and used as the basis for the formulation of two mathematical models. These models are constructed so as to investigate the effects of the parameters on each other, as well as on the overall logistics system. By employing these models, many individual modes can be established in accordance with the basic logistics requirements of the space station system. Each such mode is defined in terms of space station crew size, amount of on-board reserve requirements necessary, resupply frequency, logistics vehicle(s), and launch vehicle booster(s) to be used. With such feasible modes identified, each is evaluated against the others in terms of system criteria chosen to maximize the time available for experimentation on-board the space station, consistent with the physical constraints of the system. The manner in which these criteria are applied and the subsequent evaluation carried out constitutes a cost effectiveness analysis of the logistics system being considered. Based on this evaluation, the one mode that provides optimum logistics support is identified and recommended for implementation in the particular space station program in question.

* **3Wd. 1. On Flow Within Platoons,** ARTHUR DAOU, *The Port of New York Authority, 111 Eighth Avenue at 15th street, New York, New York.*

The headway of a vehicle in a platoon on a single lane roadway can be considered as a random variable whose expected value is a function of velocity. Data from the Holland Tunnel strongly suggests that the mean headway can be represented as a linear function of velocity, and the distribution about the mean is log-normal. In addition to describing platoon headways, the log-normal distribution allows one to set up a significance level for classifying vehicles as platoon members or non-members.

* **3Wd. 2. The Dependence Between Vehicles in Single-Lane Flow,** HAROLD GREENBERG, *New York University, New York 53, New York.*

The speeds of successive vehicles are shown to follow a stochastic difference equation. Hypothesis testing is then used to determine the order of the dependence. The results tend to show whether a driver's behavior is affected by the vehicle ahead, two vehicles ahead, three vehicles ahead, etc. The relationship between successive speeds is found, and the results are shown for various roadways.

*** 3Wd. 3. Single Lane Bus Flow,** R. Rothery, R. Silver, & R. Herman, *Research Laboratories, General Motors Corporation, Warren, Michigan; and* C. Torner, *Styling Staff, General Motors Corporation, Warren, Michigan.*

A presentation will be given of a series of experiment carried out to determine the characteristics of single lane bus flow. Using pairs of buses the theoretical "car-following" model of single lane traffic flow which had been shown by previous work to be valid for automobiles was tested for this type of heavy vehicle by studying the detailed manner in which one bus follows another. The validity of this model as applied to buses will be discussed. Experiments involving platoons of up to ten buses were also carried out to determine their stability and steady state stream properties. The results from these platoon experiments will be presented and compared with the predictions obtained from the bus following experiments. Movie films taken during the course of the experiments will be shown.

*** 3We. National Cost Effectiveness Analysis Work Session. Chairman—** Mr. Walter Edward Cushen, *Economics and Political Studies Division, Institute of Defense Analysis, 1666 Connecticut Avenue, N W., Washington 1, D. C.*

The purpose of this working session is to explore the possibilities and implications of a cost-effectiveness approach to the problem of Federal program balance. An initial attempt to systematize the problem in terms of the U.S. budget programs and benefit-vs-cost considerations will be used as the jumping-off point for discussion. Perhaps the major difficulty is that qualitative statements of national and agency goals are imperfectly matched with our ability to formulate an analytical "Objective Function."

*** 4Wa. 1. A Fast-Time Simulation Computer Model of an Automated Terminal Area Air Traffic Control System,** A. S. Jackson, and R. V. Morse, *Director of Research, Control Technology Inc., 1232 Belmont Avenue, Long Beach 4, California.*

This paper describes a generalized fast-time computer model of an automated terminal area air traffic control system. The model is based upon a single thread Monte Carlo approach and was developed for the Federal Aviation Agency to evaluate preliminary control concepts prior to comprehensive testing on a real-time terminal area experimental facility. The modular basis of the computer model which enables various approach geometrics and control modes to be selected by means of subroutines is presented. The model is shown to have the capability of including up to ten values for each of twenty parameters when applied to the simulation of a semi-factorial experiment. In addition, the simulation of each of the major elements in the automated terminal is described. These include the control computer, air traffic controller and data link, pilot, aircraft, co-ordinate transformation, and radar with track while scan capability. The data analysis portion of the model includes a point plotter device which enables either on-line ground tracks to be displayed or plotted for specified runs. Specific applications of the model are also presented. These demonstrate its utility in determining the feasibility of control concepts and in carrying out fast-time experimental studies where large amounts of data are needed when the contributions of human pilots and air traffic controllers are not critical to the outcome.

4Wa. 2. Experience with an Urban Renewal Decision Simulation Model. WILBUR A. STEGER, *Systems Research and Planning, Consad Research Corporation, 3406 Fifth Avenue, Suite 301, Pittsburgh, Pennsylvania 15213.*

Under the sponsorship of the Housing and Home Finance Agency of the U. S. Department of Commerce, the Center for Regional Economic Studies, University of Pittsburgh, and CONSAD Research Corporation of Pennsylvania, have developed a digital computer simulation model capable of representing some of the impacts of urban renewal (such as clearance, rehabilitation, or code enforcement treatments), or non-urban renewal, types of municipal development such as capital improvement plans (streets, schools, public safety, etc.) These impacts are in the areas of: population, employment, land use, social indices, housing types, market indicaters, income, growing and declining industries, 'blight indices,' and governmental measures (such as expenditure and revenue projections). As do all such models, this model basically contains several subsystems which are described in the enclosed flow diagram. Several portions of the model have already been run. The population, employment and industrial location submodels have produced results for urban decision making. The "data bank" requirements of such a model are enormous, and the centralized information system of the City Planning Department of Pittsburgh, which has taken many years to develop, is a necessary contribution to the development and useful running of such a model. In addition, experimental designs for maximizing the informational content for urban decision makers, consistent with their present decision/information system, are being developed. The assumption underlying the model and further planned refinements will also be discussed.

4Wa. 3. A General Purpose Simulation Technique for Modeling Military Operations, MARVIN KORNBLUH, RENO A. MERIKALLIO and JAMES E. O'HARA, *Washington Systems Center, IBM Corporation, 7900 Wisconsin Avenue, Bethesda, Maryland.*

A study was conducted to demonstrate the feasibility and applicability of a general purpose technique for (1) Depicting the interactions between friendly and hostile forces in executing tentative or established plans; (2) Providing a more refined approach to measuring the significance of changes in opposing force activity and potential. The technique is known as the General Purpose Systems Simulator (GPSS) developed by the IBM Corporation. It develops simulation models in terms of block diagrams and logical flow of information through these blocks. The GPSS approach has a number of advantages: (a) Enables the model-builder to form operational concepts and test these concepts on a digital computer even if he lacks knowledge of machine programming and equipment characteristics; (b) Enables the model-builder to be his own programmer eliminating the need for communication between analysts and programmers and reducing costs; (c) Decreases the time required to build simulation models and experiment with them;

(d) Facilitates initially building a simple model and gradually introducing more complexity, flexibility and sophistication. The military operations model developed was meant to be applicable to an environment in which the enemy force does not maintain fixed battle positions and hence is relatively mobile, has varying degrees of firepower, and available intelligence pertaining to enemy force structure and location is frequently unreliable. The model constructed depicted tactical operations (reconnaissance and airlift) in a limited war environment. The model was designed to be as "game" oriented as possible. Formal decision rules were prepared, assumptions explicitly stated and reasonable inputs hypothesized. Trial runs were made on the IBM 709. The study concluded that GPSS can be useful to and personally used by operationally sophisticated personnel to effectively simulate a wide variety of military operations at minimum cost. It makes it possible for operational planners to conceive format precluding the necessity to separately construct a conventional flow chart and write a computer program.

4Wa. 4. An Introduction to C.S.L., DR. J. G. LASKI, and J. N. BUXTON, *Corporate Planning Department, Esso Petroleum Co. Ltd., Victoria Street, London, S.W.1., England.*

A description of the Control and Simulation Language (C.S.L.) developed by Esso Petroleum Company and IBM (U.K.). This programming system is appropriate to the formulation of decision-making rules for scheduling in complex discrete stochastic systems and for simulating queueing systems. The underlying logical ideas, the area of its application and relevence, and the implications of its use are discussed. Examples of the use of the language and its compilation into IBM 7090 language on an IBM 1401 computer are given.

4Wb. 1. Clustering Of Defectives In Time, JOSEPH I. NAUS, *Institute of Naval Studies, Center for Naval Analyses of the Franklin Institute, 545 Technology Square, Cambridge 39, Massachusetts.*

A certain manufacturing process under normal conditions produces about N defectives a day. The quality control department's main concern is serious lapses in quality that last p of the day or less. For this reason, they feel that looking at intervals longer than p would mask the abnormal conditions by the normal. Two simple schemes are considered: (1) *Disjoint Scheme:* Divide the day into $1/p$ disjoint intervals of length p; call the process "out of control" if n or more defectives appear in one of these intervals. (2) *Scan Scheme:* Keep a running count of the number of defectives in the past period of length p; that is, continuously scan the day with an interval of length p. Call the process "out of control" if n^* or more defectives appear in the scanning interval. Every quality control scheme has a particular "level"; this is the probability of calling "out of control" given that the process is actually in control. To compare schemes (1) and (2) we give them the same level by a proper choice of n and n^*—due to the discreteness of n and n^*, randomization is necessary to give the two schemes the same level. We assume that when the process is under control that the N defectives are distributed at random over the day (we relate this to the usual assumption of Poisson arrivals). For this assumption, the level of the disjoint scheme reduces to a classical occupancy probability. The level of the scan scheme is the probability, $P(n^*|N;p)$, that there exist a subinterval of the day of length p, that contains at least n^* out of the N points. Naus [1] derives explicit formula for $P(n^*|N;p)$ for $n^* > N/2$, in terms of simple tabulated quantities. Quality control also investigates gradual lapses in quality due to worker fatigue. When the process is working normally, the times that the defectives happen are distributed at random over the day. When fatigue sets in, the defectives are more likely to occur at the end of the day; the times are in this case taken as distributed with c.d.f. $F(x) = x^k, k > 1$. The greater the effect of fatigue, the greater is k. We show that for this alternative hypothesis and $n, n^* > N/2$,

$$\text{Level Disjoint Scheme} \approx M, \tag{1}$$

$$\text{Power Disjoint Scheme} \approx ZM, \tag{2}$$

$$\text{Level Scan Scheme} \approx nM, \tag{3}$$

$$\text{Power Scan Scheme} \approx Z(nM); \tag{4}$$

where,

$$M = \binom{N}{n} p^{n-1}, \tag{5}$$

and

$$Z = \frac{k^n}{nk - n + 1}. \tag{6}$$

We use these approximate (p small) results to indicate why the scan scheme is more powerful (against the alternative $F(x) = x^k$) than the disjoint scheme. [1] Naus, J.; *Clustering of Random Points in Line and Plane*, (Unpublished Ph.D. Dissertation, Department of Statistics, Harvard University), 1963.

4Wb. 2. Redetermination of Favourable Conditions in Chemical Reactions, Geoffrey L. Cockhill, *Chemcell(1963) Limited, 1155 Dorchester Boulevard West, Montreal, Quebec.*

The empirical elucidation of the response (yield, purity, etc.) of a chemical system in terms of the controllable factors in the system is frequently accomplished by fitting quadric surfaces to data from second order experimental designs. Such representation is usually followed by reduction to canonical form, from which may be ascertained the local nature of the response surface and optimum or other favourable conditions. Implementation of these favourable conditions, regrettably, often gives disappointing results and it is concluded that the system has somehow changed. A mechanism to explain this behaviour is advanced. It is suggested that the set of unknown relationships between controllable factors—the latter usually selected merely through convenience in manipulation—and the fundamental causal variables of the system, constitute a state of the system. Not uncommonly this state may change—particularly from one series of runs to another, from reactor to reactor, and in scaleups. Follow-up runs will inevitably be disappointing if made under another state. A "disappointment" statistic is defined and its mathematical nature exhibited. Formulas are presented whereby new run disappointments are coupled with the original analysis to yield a measure of state change. By these means new favourable conditions can be determined from fewer new runs than a full design would entail. Under special circumstances a single new run suffices. A strategy of experimentation which exploits the formulas is outlined. Extensions are made to linear systems and to the simultaneous occurrence of state change and conventional block effects. An example is given.

4Wc. 1. System Evaluation Techniques Applied to the Design of a Satellite Communication System, STANLEY HAUER, *Aerospace Group, Hughes Aircraft Co., Mobile Mid-Range Ballistic Missile Division, P.O. Box 90615, Los Angeles 9, California.*

System evaluation is defined as consisting of a series of interrelated studies: market analysis; performance-design analysis; operations analysis; and cost analysis. The objective is to determine a set of optimum or efficient system specifications and operating characteristics as a function of profit or mission objectives. Although commercial systems are examined in detail the technique can be applied with modification to military systems. In the market analysis area a preliminary demand model is structured as a function of projected number of telephone calls, average duration of a call, message rate and an absorption factor to account for other-than-satellite systems absorbing some of the demand. The projected number of telephone calls is a function of the growth rate. Regression techniques are then used to correlate telephonic traffic with selected indicators of economic growth to determine growth rate by geographical area. Projections of telephonic traffic are then translated into channel requirements. The objective of performance-design analysis is to determine system growth as a function of capability or capacity. Growth, indicated by weight, size and complexity, forms a basis for costing. A series of curves can be developed indicating satellite weight and cost as a function of number of channels for example. In this way satellites can be mated with boosters, launch costs determined, and design-cost studies performed.

In the operations analysis section launch base parameters are analyzed as they relate to facility requirements (number of pads to maintain a launch rate); equipment quantities (to include the effects of launch reliabilities and replacement rates); and base and ground station personnel requirements. This data provides input to the costing activity. Cost analysis consists of developing cost factors and then structuring a cost model as a function of launch base requirements, booster design and reliability factors, satellite design and operational factors, terminal stations and data centers. A simplified launch cost equation (booster cost and launch reliability, satellite cost and placement reliability, and replacement rates) is then used to compare the random and synchronous systems. In an intersystem comparison between a submarine cable and satellite system a breakeven distance is determined beyond which a satellite system is less expensive. The results of each of the above studies are then integrated in a system evaluation section which develops a quantitative cost-effectiveness index as a function of performance and operational parameters. In addition, some econometric techniques are used to determine relationships between sales, profit and launch cost. A model is developed for profit as a function of revenue and satellite production cost. Profit s also expressed as a function of channel capacity of the system. These relationships can be used to set wage incentives for contractors and engineering and manufacturing personnel.

4Wc. 2. Utility of Partially-Failed Communications Satellites as a Reserve, Frank D. Mason, *Building 366, Mail Station 822-B, Hughes Aircraft Company, Culver City, California.*

A communications satellite with multiple channels must maintain operation with some minimum number of channels or it becomes necessary to launch another satellite to replace it. The question then arises as to the disposition of the original satellite. For some optimal mixture of economy and service quality, should the remaining channels in the old satellite be used until they fail, replacing them with new channels in the new satellite? Should the old satellite be turned off and held in reserve for the possibility that the new satellite may fail unexpectedly? The use of reliability and failure rate predictions to provide the basic information enabling optimal replacement decisions to be made and to determine the effects of policies regarding a satellite reserve is described in this paper.

4Wc. 3. Scheduling in a Multiple Satellite Environment, Robert A. Totschek, *System Development Corp., 2500 Colorado Avenue, Santa Monica, California.*

Recently, the Satellite Control Facility, SCF, operated by the U.S.A.F. in Sunnyvale, California, has expanded from a single satellite to a multiple satellite control capability. The guiding principle of operation in a multiple satellite environment is that each satellite vehicle time-shares component equipments of the SCF in accordance with its requirements and its priority among the set of active vehicles. This paper discusses the techniques used for applying this principle by the computer program for multiple satellite scheduling operations, called SCHOPS. SCHOPS predicts the satellite environment for the schedule interval. Considering the tracking, telemetry, and commanding requirements of each satellite, SCHOPS determines when conflicts for SCF equipments will arise during the interval. Using a dynamic priority logic, SCHOPS resolves these conflicts and produces co-ordinated schedules of activities for the SCF. Scheduled activities include the following: 1. Determination of the times at which each satellite is to be serviced by specific tracking stations. 2. Assignment of computer time at the control center for running associated support programs. 3. Allocation of communication lines between the control center and remote tracking stations. 4. Scheduling of equipment maintenance at the SCF. The paper is primarily concerned with the problems of multiple satellite scheduling and the workings of the dynamic priority logic, but some space is devoted to the options available to the computer program users who are the ultimate decision makers.

4Wc. 4. Approximations for Satellite Distributions, Richard F. Link, *Statistical Techniques Research Group, Princeton University, 167 Nassau Street, Princeton, New Jersey.*

The mathematical expressions for the distribution of the number of launches required to put up a satellite system (putting up distribution) and the distribution of the system outages (system is incomplete because of satellite deaths) tend to be rather complicated functions of satellite mean life, satellite life distribution, number of launch pads, launch pad turnaround time, launch reliability, launch protocol, and, also, for the outage distribution, the precise nature of the satellite configuration. The characteristics of these distributions can sometimes be rather well approximated by simple models. Comparisons are presented between the results of a detailed investigation taking into account all relevant factors, and approximations utilizing many simplifying assumptions for a three position, six satellite (two satellites per position) synchronous (24 hour orbit) satellite system. The detailed putting up distributions are compared with a model derived by Rose and Rojansky. The outage distribution is compared with a simple system assuming exponential lives and constant.launch rates. In general, the approximate results agree closely enough with the more exact results to give useful insight into system behavior. Thus decisions which are not sensitive to the fine structure of system behavior can safely be made using such approximate results.

* 4Wd. 1. The Action Point Model of the Driver-Vehicle System, E. P. Todosiev, *The Ohio State University, Department of Electrical Engineering, 2024 Neil Avenue, Columbus 10, Ohio.*

The action point model is a statistical mathematical model of the driver-vehicle complex and is based on the threshold sensitivities of the human driver to the physical variables of relative velocity and acceleration. This model deals specifically with the car-following situation but the basic concepts of the model are general enough such that the model could be developed to completely describe the driver-vehicle system as well as the interaction between vehicles in a platoon of vehicles. In this model, it is shown that the driver uses a perception-action process in controlling his vehicle. Since the driver makes repeated use of this process, it can be considered as a highly overlearned process and consequently the driver performs in an automatic fashion in the sense that he is not aware of either the stimulus or the resultant response. The perception-decision-action process is employed to show how the driver maintains stability in car-following.

* 4Wd. 2. Optimum Control Of A System Of Oversaturated Intersections, Denos C. Gazis, *Watson Research Center, I.B.M., P.O. Box 218, Yorktown Heights, New York.*

The problem of optimizing the control of two oversaturated traffic intersections has been treated using the semi-graphical methods employed in a previous paper for an isolated intersection. As in the case of a single intersection the optimum control is of a bang-bang type, along edges of the control region, which in this case is defined by the permissible ranges of the green phase splits. An analytical formulation of the method using Pontriagin's control theory will also be given.

4Wd. 3. Transportation Science Section Of O.R.S.A. Business Meeting, *CHAIRMAN*—Leslie C. Edie, *The Port of New York Authority.*

4We. 0. National Cost Effectiveness—Work Session.

(For abstract of this session please see 3We. 0)

* **1Ta. 1. Role of Cost in Military Decisionmaking,** WILLIAM A. NISKANNE, *Director, Special Studies, Office of the Assistant (Comptroller), Department of Defense.*

The paper, although taking account of the importance of cost in currently operational systems and those being considered for initial procurement for inventory, will focus on the particular challenges and problems of applying analytical tools to system design and general military objectives for the periods 5, 10, and 15 years in the future. Resource requirements or cost is a major parameter in these studies.

* **1Tb. The Practice of Operations Research,** CHAIRMAN: DR. HUGH MISER, *The Mitre Corporation, Bedford, Massachusetts.*

The purpose of this session is to explore issues of current concern relating to the practice of operations research as a profession. Such matters as these are candidates for discussion at this session: the proper roles of OR consultants, client-consultant relations, controlling the quality of OR work, ethical principles, and the publication of case histories relating to work on problems from environments subject to military or industrial security. In order to single out the issues of greatest mutual concern and concentrate the discussion on them, the session will have three parts: In the first part each panelist will make a brief statement, in the second part the panelists will comment on these statements, and in the third part the audience will be asked to join the discussion.

1Tc. 1. On Round-Off Errors in Linear Programming, HEINER MULLER-MERBACH, *University of California, Operations Research Center, Richmond Field Station, 1301 South 46th Street, Richmond, California.*

During linear programming procedures round-off errors arise which are to be reduced by reiteration techniques. The paper presents the results of an investigation that deals with how these errors cumulate, how they may grow to a value which impairs the significance of a solution seriously, and what kind of easily computed parameters correlate to the mean value of round-off errors. Besides that, the influence of setting equal to zero those matrix elements which obviously consist only in round-off errors has been evaluated. The aim of this evaluation was to learn about the importance of error elimination and to find out the useful frequency of reiterations. The Normal Simplex Method and both the explicit form and the product form of the Revised Simplex Method have been considered. The computer runs were begun on the NCR 803B and continued on the IBM 7090. The test problems were those of the SCEMP Project and others.

1Tc. 2. Location-Allocation Problems in the ℓ_1-Metric, A. CHARNES, J. E. QUON AND S. J. WERSAN, *Northwestern University, Evanston, Illinois.*

The ℓ_1-metric is applied to a certain class of location-allocation problems reducing them to linear programs with integer requirements. The properties of the ℓ_1-metric are used to establish a theory of "median sets" which underlies an algorithm yielding local optima with-out recourse to actual solution to the linear programs.

1Tc. 3. Maximizing the Information Value of a Linear Programming Model, DONALD W. JOHNSON, *Vitro Laboratories, 14000 Georgia Avenue, Silver Spring, Maryland.*

Most practical decision making problems involve many variables, and high degrees of uncertainty in parameter values, and the utility function. In order to determine how many dollars to spend on reducing the uncertainty via increased sampling and improved approximation, or to determine how to save computation time and/or money via approximation, or eliminating variables, one must maximize information value (gain less cost). This decision theoretic approach is applied to the problems of deciding how much precision should be accepted in linear program cost, stipulation, and co-efficient values. The methods discussed will involve much more than the usual sensitivity analyses occasionally discussed in the literature. A method for estimating how much money to spend on improving information quality, and for deciding how to spend it will be presented, and applied to a linear programming problem.

* **1Td. 1. Gap Acceptance Probabilities,** DONALD P. GAVER, *Carnegie Institute of Technology, Pittsburgh, Pennsylvania.*

* **1Td. 2. Gap Availability And Acceptance at a Left Side and Right Side on Ramp,** ADOLPH D. MAY, JR., *State of Illinois Department of Public Works and Buildings, Division of Highways, 160 North La Salle Street, Chicago 1, Illinois.*

A ramp metering device has recently been installed to automatically adjust the maximum allowable ramp volume according to the expressway traffic density level in order to maintain satisfactory operation on the expressway. A study of gap availability in the shoulder lane in advance of the ramp, and the acceptance of gaps by ramp vehicles is now under way. The purpose of this study is to revise the metering scheme at the presently controlled ramp and to develop a metering scheme for two additional ramps which will be controlled in the near future. The Pilot Detection System permits the recording on punch paper tape, the arrival times of individual vehicles, and one characteristic of the vehicle or traffic flow, such as traffic density. For each density level, time headway distributions are determined and attempts are being made to express the distributions mathematically. Time lapse photography is employed to obtain gap acceptance data for each ramp being studied, and for various density levels. Again, an attempt is being made to express the gap acceptance distribution mathematically. The combining of the two distributions will result in the predicting of the number of acceptable gaps for various density levels. This knowledge will permit a greater insight in selecting the ramp metering level for various densities.

* **1Td. 3. Stochastic Traffic System, Whose Service Times Increase with Occupancy,** WALTER HELLY, *The Port Of New York Authority, 111 Eighth Avenue, New York, New York.*

Some traffic service systems are characterized by service times which increase with the number of patrons undergoing service simultaneously. Certain examples, including the placement of toll telephone calls and the operation of a road traffic circle, are modelled to explore this property. It is shown that the traffic capacity of such systems can be maximized only if some of the customers are rejected or retarded.

* **1Td. 4. Maintenance of Commuter Train Schedule,** G. F. NEWELL, and R. B. POTTS, *University of Adelaide, South Australia.*

The maintaining of a regular schedule is important for the satisfactory and efficient operation of a bus or train service. The way in which a deviation from the regular schedule tends to amplify and give off-schedule running is investigated for a simple mathematical model in which customers have a time independent rate of arrival at each stop. It is shown that as trains pick up passengers there is a tendency for them to pair together because a late train must serve more customers and will get further behind schedule but the next train will serve fewer customers and get ahead of schedule.

* **2Ta. 1. Concepts of Resource Analysis,** MAJOR GENERAL ROBERT J. FRIEDMAN, *Director of Aerospace Programs, Office of the Deputy Chief of Staff, Programs and Requirements, Headquarters, U.S. Air Force.*

This paper will be the first of two presentations which will be given in the invited session on Concepts and Methods of Military Cost Analysis. It will cover concepts such as incremental cost; major resource flow—Research, Development, Test and Evaluation required to attain a capability for the military forces, initial investment required to install the proposed new system(s) in the operating inventory and recurring or annual costs that must be met each year throughout the life of a system; as well as the major resource categories that must be identified to insure comparability in costs—different aircraft or aircraft compared to missiles, carrier-based aircraft or ground troops.

* **2Ta. 2. The Use of Cost Analysis in the U.S. Navy,** CAPTAIN EVAN P. AURAND, *Office of the Chief of Naval Operations.*

This paper will be the second of the two presentations which will be given in the invited session on Concepts and Methods of Military Cost Analysis. It will cover the application of presently available concepts and methods of cost analysis. An actual case will be used drawn from current experience of the United States Navy. This will be a description of the problems encountered and the steps taken to provide more adequate information for the decisionmakers at every level of action.

* **2Tb. The Practice of Operations Research (Continued): Invited Session,** (For abstract see 1Tb.)

2Tc. 1. Methods for the Solution of Fractional Linear Programming Problems, H. C. JOKSCH, *The Mitre Corporation, Box 208, Bedford, Massachusetts, U. S. A.*

Our problem is to maximize the quotient or another fractional linear function of two linear functions whose variables are constrained by linear equations and/or inequalities and have to be non-negative. Some methods for the solution of one of these problems have been published. We present a new method which is applicable to a broader class of problem than the known ones. We reduce the problem to a parametric linear programming problem. If we keep the value of a denominator in the objective function fixed, we have a problem with a linear objective function remaining. Solving this problem with the value of the denominator as a parameter parametrically, we can obtain the optimal solutions and identify them by the use of one entry in the simplex tableau.

2Tc. 2. The Menu Problem, JOSEPH L. BALINTFY DR. ENG., *Associate Professor of Operations Research School of Business Administration, Tulane University, New Orleans.*

Decisions concerning the nutritional qualities and cost of food service in institutions are made in the form of menu planning. The objectives of menu planning expressed by mathematical programming models leads to a set of problems, called "menu problems" which are concerned with finding the optimum combination of menu items satisfying specified nutritional, structural and variety requirements for a sequence of days. For non-selective menu plans the menu problem is identified with a bounded variable integer programming version of the well known diet problem. Experience with the use of two conceptually different computer codes—one with on-line adjustment option—is available, and results indicating up to 30 per cent potential cost saving are demonstrated. For selective menu plans, the methodology and outline of the use of several non-linear programming techniques is discussed.

2Tc. 3. Schedule-Sequencing Problems, HENRI L. BEENHAKKER, *Stanford Research Institute, Menlo Park, California.*

A number of commodities, with routing specified, has to be scheduled on a number of facilities, such that an optimum is obtained for the integrated production process. A commodity can have two or more specified routings. Associated with each commodity there is a set-up cost, which depends on the product manufactured immediately prior to the one under consideration. The resulting schedule is optimum with respect to set-up costs, total processing time, idle time of facilities, production rate and workforce requirements. Some of these factors are diametrically opposed. Two factors A and B are diametrically opposed if and only if a production process which is optimum with respect to A implies that the production process is definitely not optimum with respect to B. For instance, total processing time and workforce requirements are two factors which are diametrically opposed; a schedule which results in a minimum total processing time shows in general a high variation in workforce requirements and a schedule with stable workforce requirements has a long total processing time. The optimum schedule is obtained by balancing out the economies and diseconomies of the factors which are diametrically opposed. A combination of scheduling and linear programming techniques is applied.

* **2Td. 1. Two Problems in Scheduling Manpower,** A. M. LEE, and R. W. LINDER, *Trans Canada Air Lines, Place Ville Marie, Montreal, Quebec.*

In a reservation office there are several tasks which vary in size throughout the day. The reservations telephone answering workload is governed by customer habits; the workload relating to control of passenger check-in at departure is governed by the flight-schedule. The problem forecasting the workload in any period and in scheduling the minimum manpower resources to handle it whilst retaining certain service standards are described. These are case-histories.

*** 2Td. 2. Optimizing Performance in an Automatic Freight Car Classification Yard—An Interim Approach.,** C. E. LAW, D. C. LACH, AND G. V. JACQUEMAIN, *Canadian National Railways, Department of Research & Development, P.O. Box 8100, Montreal, Quebec.*

In automatic classification yards, freight cars are released at the crest of a hump, automatically switched into tracks according to their destination, and retarded to ensure coupling at a suitable speed. The required release speed of a car from the last retarder is predicted by an analog computer from measurements of the acceleration of the car on a known grade and from measurement of the distance to point of coupling on the destination track; over 250 coefficients used in the predictions can be varied. Management's dissatisfaction with the number of overspeed impacts received by cars led to the formation of an OR team to "evaluate the performance" of one of CN's yards. Preliminary tests revealed a large number of significant variables (track, track condition, car type, car weight, etc.), and sampling procedures were developed to cope with this problem. It was concluded that substantial modifications were necessary to produce acceptable performance. The tracks whose improvement would yield the greatest return in the shortest time were identified by a computer traffic analysis, and empirical adjustment of computer coefficients relating to these tracks was carried out. Methods of reducing variance of performance were examined, leading to extensive lubrication tests. Severe physical restraints limit the reassignment of traffic from one track to another, but the first steps towards an optimum reassignment were taken. Work is proceeding on optimization of the total hump yard system, including consideration of damage to cars and contents, throughput time, operating costs, and possible equipment modifications.

*** 2Td. 3. Simulation Models of Railway Terminal Operations,** FREDERICK A. KOOMANOFF, *Department of Engineering Physics, Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio.*

The modeling of a freight classification yard represents a major simulation modeling problem. The combinatorial possibilities and various decision rules and procedures involved in determining priorities of car movement and methods of physically handling cars are extensive. Simulation of mainline movement of trains in railroading has received the major research attention because of the more clearly defined boundaries represented by this physical process. A first-generation simulation model of terminal operations has been developed at Battelle as part of the Railroad Systems Research Group study of freight transport operations. When the entire model is completed, evaluation of changes in input volume, sequence, and times may be made as well as analysis of changing policy rules, physical plant, physical equipment such as switch engines, etc. The present model can approximate many solutions. A simulation model of the diesel service area has been completed. This model processes locomotive units through a diesel service area and permits study of changes in personnel, routing, input or output schedules, procedures, work rules, etc. The discussion will describe these models indicating the understanding of a complex system that can be gained by development of dynamic deterministic models. Probabilistic aspects of input, e.g. number of bad order cars, etc., can be handled by standard Monte Carlo methods outside of the model, permitting more flexibility in the study of terminal and diesel service area problems.

3Ta. 1. Generalized Cost Models for Very Large Programs: National Space Program Application, DR. GEORGE W. MORGENTHALER, GEORGE FOSDICK, and DR. R. S. NOVOSAD, *Martin Company, Denver Division, Denver 1, Colorado.*

The creation of a model to be used as a planning tool for the efficient allocation of funds among the various projects that constitute a very large program is described. The particular application confronting the authors pertained to the National Space Program. Questions of the nature of "In what particular space technologies should R & D be supported?", "How does the timing of a given space vehicle development project affect the entire program?", "What are the indicators which can be used to judge the economic consequences of the total Space Program?" are discussed. The mathematical description of the approach to this Space Program problem has the same formalism as other large resource allocation problems. The interest and challenge lie in the following aspects of applying the theory to a program of such magnitude: 1. Not only is there no clear cut picture, but there is sharp controversy as to what the goals and benefits of such a program are. 2. Cost and value parameters abound and are difficult to quantize so as to be on a comparable scale, i.e., risk to life, military worth, national prestige, acquired scientific knowledge, etc. 3. The restraints are not easily obtained. The total funds available for space projects over the next several decades are difficult to estimate. The same is true of the performance that will be obtained from the launch vehicles and space systems proposed but for which real performance and reliability data are not available. 4. The "state" of a space program at any given time may be described as the projects which are active at that time. Not only is much expert opinion needed to predict the space projects of the future, but the state is difficult to formalize for model usage. Contrasts between model building and making a program study are made. The model maker has imposed on him the following requirements. 1. Flexibility: Value judgments must reflect the varied opinions of the model users, not those of the model maker. The user must be allowed to input his projection of future space developments and to choose space missions that he considers essential. 2. Convenience: The detailed preparation of data, lengthy calculations, and a great deal of technology must be short circuited by the model. At the same time, employment of the model should not require much study or special skills in order that it can be used by top level decision makers. 3. Credibility: The data and analytic methods necessarily lack accuracy (it is difficult to obtain a good picture of costs of past programs, much more so to obtain costs for a poorly defined concept). The implications of studies made with the model must be consistent with these shortcomings. Finally, questions such as whether launch vehicles should be designed so as to be recoverable are used to point up the need for models capable of looking at very large programs in their entirety.

3Ta. 2. Stochastic Nature of Military Cost Analysis, ALFRED G. ASWAD, *Douglas Aircraft Company, Inc., Santa Monica, California.*

During a Total System Cost Analysis of a Manned Orbital Space System the author was confronted with the problem of what is known in military costing circles as requirements uncertainty. This was not due so much to uncertainty in the configuration of the system being costed but due to the stochastic nature of the number of launch vehicles, ferry vehicles, resupply vehicles, etc., required to complete the total mission. This problem was induced by reliability considerations. Two statistical techniques are presented which offer methods of dealing with this problem together with a preferred technique.

3Ta. 3. Military Cost Effectiveness of Advanced Manned Aircraft Systems, WILLIAM E. DICKISON & RODERIC M. DIXON, *Systems Engineering Group, Research and Technology Division, Airforce Systems Command, United States Air Force, Wright-Patterson Air Force Base, Ohio 45433.*

A weapon system is, by definition, composed of equipment, skills, and techniques, the composite of which forms an instrument of combat, usually but not necessarily, having an air vehicle as its major operational element. A weapon system may be divided into four interrelated elements: (1) a vehicle, (2) a military task or mission, (3) the personnel, materiel and facilities required to make the vehicle operationally effective to perform the specified tasks, and (4) an operational plan for employing the vehicle, personnel, etc., to perform the specified task. Implicit in the definition of a weapon system is the requirement for a definite quantity of vehicles. Each element of the definition is essential. A significant change in any of the elements may materially affect the cost. It is, therefore, essential that all elements of a weapon system be spelled out explicitly before any cost analysis or operations analysis of the weapon system is undertaken. When changes in the quantities or phasing of the vehicles are made, it is important to determine the effect of such changes on the military task and operational plan which in turn determine the personnel and support requirements. Substantial errors in cost may be introduced if this is not done. There are many problems in attempting to assign operating costs to a particular weapon system. These difficulties arise independently of the characteristics of the weapon system, of the type of cost being computed, or of the cost method employed. For example, a large part of the Air Force assets are common to more than one weapon system, thus creating a problem of joint cost allocation. Further, allocation methods suitable for historical weapon systems may not be adequate for projecting costs of future weapon systems. Like most enterprises, many Air Force activities involve certain fixed costs incident to being in existence. Since these costs are fixed in total, the cost per unit or system varies with the number of units or systems. It is also possible to effect substantial cost adjustments by changing the operation of a weapon system without changing the quantity or phasing. These Operational Changes may be in readiness, deployment, maintenance concept, base configuration or mission. There is some evidence that costs attributed to a weapon system depend on the size and composition of the rest of the Air Force. If we phase in a new system during a period when the Air Force is contracting in size, many assets already paid for may be used by the new weapon system. Facilities may be available for the cost of modifications. If, however, the new weapon system is introduced during a period of overall Air Force expansion, these resources and facilities may have to be purchased new, and the costs assigned to the new weapons system resulting in a much higher total system cost. These conditions contribute to a region of uncertainty surrounding the cost of a weapon system. Such costs are adequate to effect a choice based on a cost-effectiveness comparison between two or more design variations of the same basic weapon system or between two closely similar weapon systems. Practitioners of operations research sometimes need to remind themselves that cost is not synonymous with value and that cost is not a suitable basis for comparison unless value can be measured independently of cost. Data for this paper will be from current studies conducted by the Operations Research Division, such as CX-4, CX-6 or AMP.

* **3Tb. Mathematical Biology & Operations Research,** CHAIRMAN—DR. E. W. PAXSON, *The RAND Corporation, Santa Monica, California.*

This session is a panel discussion exploring the possible future interface between mathematical biology and operations research. It is hoped that the discussants will touch on such topics as: (1) Command and Control; (2) "Nervous" Systems for Automation; (3) General Problem Solvers; (4) Pattern Recognition; (5) Systems Questions Involving Hardware Arising from Bionics; (6) Physiological Systems and Man-Machine Interactions; and (7) Applications in Clinical Medicine.

3Tc. 1. Network Algorithm for the Traveling Salesman Problem, JOHN W. SUURBALLE, *Bell Telephone Laboratories, Inc., Murray Hill, New Jersey.*

There are several ways to represent the set of $(n-1)!$ traveling salesman tours through n cities as a subset of origin to destination paths in a network, with path length in the network corresponding to tour length for the salesman. In these networks there is a non-negative, but generally positive, separation between shortest path length and optimal tour length. In two such networks, algorithms for the optimal tour (and in general, kth optimal tour) have been developed combining three procedures: (a) A simple linear program for certain branch distance perturbations which minimize the separation between shortest path length and optimal tour length. (b) A path-partitioning algorithm for separating the paths through an arbitrary subnetwork from the remaining paths in the network, by terminating them at separate destination nodes. (c) An algorithm for determining shortest paths between origin and destination in the network. The program applies to distance matrices with arbitrary real numbers, non-symmetric in general. It finds all optimal tours, and may be continued to find the set of all kth optimal tours. Computing experience will be discussed.

3Tc. 2. The Sequential Unconstrained Minimization Method for Nonlinear Programming, ANTHONY V. FIACCO, GARTH P. MCCORMICK, *Research Analysis Corporation, McLean, Virginia 22101.*

The present method is based on a formulation proposed by C. W. CARROLL ("The Created Response Surface Technique for Optimizing Nonlinear Restrained

Systems," JORSA, Vol. 9, No. 2, 169–184, March–April 1961). A smoothing function is defined that makes it possible to convert the original constrained minimization problem into a sequence of unconstrained minimization problems. Theory supporting the validity of the method has been extensively developed. Significant extension of the original approach has been possible and several of the more important results will be given, such as the primal-dual character of the method, the solution of a sequence of feasible sub-problems, and the relating of the problem variables to a single parameter. Another extension permits the introduction of a large class of equality constraints in the problem. The convergence proof of the method will be outlined, for the problem specifying both equality and inequality constraints. The method has been implemented with considerable success. The computational algorithm, based on a second-order gradient technique, will be described and computational experience indicated.

3Tc. 3. A Stochastic Personnel-Assignment Model, WILLIAM R. KING, *Operations Research Group, Case Institute of Technology, Division of Organizational Sciences, University Circle, Cleveland 6, Ohio.*

Personnel assignment decisions involve (a) predictions of job success from test scores etc., and (b) the determination of optimal assignments on the basis of these predictions. If some simple additive performance measure (e.g., "hours to perform the task") is available, multiple regression techniques may be used to obtain predictions and a linear programming assignment algorithm may be used to select the optimal assignment. Alternately, researchers have recognized the similarity between this programming approach and problems of statistical discrimination. Discrimination analysis has been rejected for such problems however, because of its restrictive assumption that each individual to be assigned is a member of one and only one job population. This paper incorporates aspects of statistical discriminatory analysis and linear programming in a probabilistic personnel assignment model which assumes that (a) no quantitative performance measure is available, and (b) each individual to be assigned may perform any job.

3Td. 1. Adjustment of Regional Boundaries to Keep the Contained Workload Within a Prescribed Tolerance, J. C. CLAPHAM, *Head—Operations Research Section, British Columbia Research Council, University of British Columbia, Vancouver 8, B.C.*

An area is divided by boundaries into a number of smaller regions for many purposes, e.g. for the distribution of milk or furnace-oil or for the collection of refuse. Periodically the workload within any set of boundaries will move out of a prescribed tolerance. Such movements may be drastic, caused for example by the introduction of larger trucks or by alteration of the frequency of service. Alternatively they may be gradual, caused by changes in the type of service required through apartment construction, new housing developments and so on. The problems involved in adjusting the boundaries to cause minimum disruption to the crews and customers are discussed.

3Td. 2. Vehicular Traffic Control—A Time-Space Design Model, L. A. YARDENI, *IBM Corporation, General Products Division Development Laboratory, Monterey & Cottle Roads, San José 14, California.*

This paper describes the basic concepts and mathematical formulations employed in a computer program developed by the author. This program provides the Traffic Engineer with a tool for either the off-line design of traffic signal progressions for fixed-time control, or the on-line computation of control variables for real-time computer signal control. A least-squares fit model is used to derive linear unispeed through bands for given volume requirements and within given limits of speeds and cycle times. An algorithm for offset computation with three-phase design capability is included in the paper. The formulation is further extended to multi-speed progressions. An approach to the network signal control problem is also outlined.

3Td. 3. Optimal Selection of Commercial Aircraft, GRAHAM D. CLAPP, *Operations Research Group, Case Institute of Technology, University Circle, Cleveland 6, Ohio.*

A method of determining the optimal air fleet composition for commercial passenger services is presented, and is applied to fleets of U.S. domestic airlines. The method is applicable to forward fleet planning, given forecasts of air traffic demand. It is concluded that currently fleets are not optimal and that the acquisition of supersonic aircraft cannot be justified. The value placed by the customer on various combinations of total trip time and distance is inferred from a study of existing patronage and tariffs on airline services. The volume of traffic is analyzed with respect to distances moved. Productivity of a transport aircraft is expressed in terms of cruising speed, payload, length of haul, availability, load factor, ground handling time and air traffic control delays. Sensitivity of the solutions to the model is analyzed with respect to the various assumptions and approximations used. No attempt is made to set up and solve a model of interairline competition.

4Ta. Military Costing Analysis, (Continued).

4Ta. 1. Logistics Cost Effectiveness, R. L. WIESS, and L. R. GUTSTADT, *Advanced Logistics, Space and Information Systems Division, North American Aviation Inc., 12214 Lakewood Boulevard, Downey, California.*

The purpose of the paper is to show methods of calculating costs and effectiveness values and how they may be combined to seek a nearly optimum Logistic system set of values. These methods are best utilized in a development period but could be used during program definition. Detailed, yet generalized cost categories are outlined to show required Logistics functions and how the cradle to grave cost is allocated among various classes of items, such as services, equipment, facilities, etc. New approaches are shown to allow the decision maker to put more of his qualitative judgements on a quantitative basis. Parametric equations are developed for the effectiveness of various field service, maintenance/maintainability, publications, supply support and training concepts. A weighting function is also presented along with a method for combining the effectiveness of sub-systems.

4Ta. 2. Assignment of Errors to Aerospace Cost Equations, PETER J. CRUMBINE, *Manager Cost Effectiveness Evaluation, Lockheed Missiles & Space Co., Sunnyvale, California.*

For the purpose of estimating costs associated with military and space programs, many mathematical models have been developed. These models can be classified according to the level of costing achieved. For example, Model 1 may estimate the total cost of a booster while Model 2 may estimate the cost of each stage separately and add the estimates to arrive at the total. The purpose of using a more refined, time-consuming model is the expectancy of lower error and increased credibility. Even though this additional effort is often spent, the reduction in error achieved is seldom measured. There are at least three reasons for this situation: a) standard error calculations (correlation measurements) are tedious and time-consuming, b) error estimates are generally not required by the customer, c) aerospace cost equations are often based on a very small number of data points and large extrapolations are sometimes required, both of which reduce the validity of a normal correlation analysis. For instance, a relationship based on only two points will have zero correlation error, even though the actual error involved may be quite high. The first of these causes, time-consuming calculations, is quickly overcome with the use of computers, which are now generally available. This paper will briefly describe one such program which is applicable to any cost equation. The second factor, lack of customer demand, introduces the matter of professional responsibility. It can be argued that a cost estimate with no assignment of error is useful only for showing relative costs and is not valid as an absolute estimate. Even so, cost estimates are often used and quoted widely in absolute terms. It then becomes the responsibility of the analyst to inform the user of the large probable error that is inherent in the estimate, even though it is not a contractual requirement. Furthermore, there is the possibility of this becoming a standard customer requirement in the future. The third problem, lack of sufficient information on which to base a correlation analysis, is the primary subject matter of this paper. In addition to the normal error due to scatter, it discusses two other sources of error. These are: (a) Insufficient data points; (b) Extrapolation beyond the range of data points. All three sources of error are dealt with separately and then integrated to achieve a single standard error factor for a general cost equation. This meausre is then used to show the improvement in accuracy that is achieved by using a more refined level of costing. Finally, a computer program (in FORTRAN and in ALGOL-60) is included for finding the overall standard error associated with an aerospace cost estimate.

4Ta. 3. Evaluation of Complete System Costing, THEODORE BULLOCKUS, *Executive Advisor, Douglas Aircraft Co. Inc., Long Beach, California.*

Complete system costing, particularly if time-phased, provides the Military Establishment with financial information desirable for budgetary purposes, and with the probable economic resource impact. More important, however, complete system costing provides the system analyst with basic information for cost-effectiveness analyses and sensitivity analyses. However, certain aspects of complete system costing are subject to interpretation and consequently may involve errors of judgement. Other aspects, particularly in methodology, may result in basic errors that are multiplied by use of percentage factors. Accordingly, those basic cost elements, methodologies, and estimating procedures which may cause errors are discussed in detail, and recommendations are given to maximize the accuracy of the costing procedure.

4Ta. 4. Common Proposal Strategies for Both Military and Commercial Opportunities, John H. Tinley, *Advanced Plans, Engineering and Product Development, Aircraft Division, Douglas Aircraft Company.*

The proposal is the means of presenting a capability for an anticipated requirement. As the proposal may present the same capability to both the industrial and military customer, it would appear that the proposal strategies should have a commonality. This paper will validate the strategy commonality and further illustrate how decision theory structuring and marginal analysis can provide a more meaningful strategy framework than the intuitive process typically applied by management. By way of demonstration, a proposal relating to a hypothetical industrial/military aircraft program is described; a set of strategies relating to this proposal effort are then evaluated to illustrate the commonality and appropriateness of the proposed methodology. The outcome of this methodology which presents the strategies as a multi-competitor game is meant to provide more than an intuitive pre-proposal plan; it is a scientific tool to provide additional knowledge to the responsible management. *Credit:* The methodology presented was developed at Douglas Aircraft Division under company sponsored Research & Development funds supplementing engineering research work accomplished by the author at U.C.L.A.

* **4Tb. Mathematical Biology & Operations Research, (Continued).** (For abstract see 3Tb.)

4Tc. 1. Sensitivity Analysis of Multi-terminal Flow Networks, Salah E. Elmaghraby, *Associate Professor, Department of Industrial Administration, Yale University, New Haven, Connecticut.*

Given an undirected flow network with finite arc capacities, an algorithm is developed for the determination of the effect of a reduction (or increase) in the capacity of any arc on the maximum flow between any two nodes of the network. The algorithm is based on the Gomory-Hu construction of "cut-trees".

4Tc. 2. On Some Numerical Difficulties Associated with Dynamic Programming, G. S. Tracz, *Department of Industrial Engineering, University of Toronto, Toronto 5, Ontario.*

It is shown by an example (the bounded brachistochrone problem, for which an analytic solution is known) that in the numerical solution of minimum-time trajectory problems using dynamic programming, a finer grid can give worse results than a coarse grid in the sense of yielding optimal trajectories with greater minimum times.

4Tc. 3. Optimum Design of Open Pit Mines, H. Lerchs, F. I. Grossmann, *International Business Machines Co., 615 Dorchester Boulevard, Montreal 2, P.Q.*

An open pit mining operation can be viewed as a process by which the open surface of a mine is continuously deformed. The planning of a mining program involves the design of the final shape of this open surface. The approach developed in this paper is based on the following assumptions: 1. The type of material, its mine value and its extraction cost is given for each point; 2. Restrictions on the geometry of the pit are specified (surface boundaries and maximum allowable wall slopes); 3. The objective is to maximize total profit: total mine value of material extracted minus total extraction cost. Two numeric methods are proposed: A single dynamic programming algorithm for the two dimensional pit (or a single vertical section of a mine) and a more elaborate graph algorithm for the general three dimensional pit.

4Td. 1. A Queueing Approach to Traffic Light Phasing, P. ROBILLARD, and PAUL NAOR, *Department of Statistics, University of North Carolina, Chapel Hill, North Carolina.*

In this study traffic light phasing is considered to be associated with the wider problem of interrupted service in queueing systems. Such problems have been recently discussed in the literature (GAVER (1962), KEILSON (1962), THIRUVENGADAM (1963), AVI-ITZHAK and NAOR (1963)). The special feature of the traffic light phasing problem is the deterministic pattern of the cycle whereas in previous studies on interruptions Poissonian breakdown assumptions were made. Furthermore, for the purpose of optimally choosing the duration of the various phases, an essential link in the analysis in the assumption of a constant clearing time (associated with the yellow light). Some expected delay times are derived and computational procedures for optimization are given.

4Td. 2. Synchronizing Traffic Signals for Maximum Bandwidth, JOHN D. C. LITTLE, *School of Industrial Management, M.I.T., Cambridge, Massachusetts,* and JOHN T. MORGAN, *Department of Statistics, Australian National University, Canberra, A.C.T., Australia.*

An algebraic method has been developed for synchronizing traffic signals to maximize bandwidth. (By *bandwidth* is meant that portion of a signal cycle during which a car could start at one end of a street and, by travelling at preassigned speeds, go to the other end without stopping for a red light.) Two problems are solved: (1) Given an arbitrary number of signals along a street, a common signal period, the green and red times for each signal, and specified vehicle speeds in each direction between adjacent signals, synchronize the signals to produce bandwidths that are equal in each direction and are as large as possible. (2) Synchronize to favor one direction with larger bandwidth and keep bandwidth in the other direction as large as is then possible. The method has been programmed for a digital computer and has been used to synchronize signals on a street in Cleveland.

4Td. 3. Some Quantitative Findings of Simulated Congestion, HANS VON CUBE, *Traffic Research Corporation Limited, Toronto 4, Ontario.*

It is common knowledge that where traffic facilities are overtaxed congestion becomes a key variable about which many travel decisions revolve. 1. Peak-hour drivers will alter their choice of travel routes as necessary to minimize travel time and to avoid points of congestion. 2. Automobile users will select the transit mode if possible when auto travel time and costs become excessive. 3. In time, traffic congestion affects the accessibility between urban areas or parts thereof, inducing people to travel elsewhere. 4. Ultimately, the nature of traffic congestion—or lack thereof—affects the nature of land use development. In traffic planning practice the resultant effect of the combination of the various behavioural travel choices have been frequently neglected. The paper briefly describes the methods used in accounting for these effects and discusses the results of a number of studies showing the impact on the total travel patterns resulting from various transit systems, expressway systems, rail commuter systems, and bus feeder systems. The necessity of developing new criteria for evaluating traffic facility systems is discussed.

4Td. 4. Simulation of a Transportation System Operating, Different Fleets of Vehicles, M. STADE, *Senior Engineer, Department 839, Canadair Limited, P.O. Box 6087, St. Laurent.*

The simulation considered is that of a transportation system in which the services of different fleets of vehicles (each fleet being homogeneous) are integrated. In such a system the fleets generally operate over different routes of the network, and loads are transferred from one type of vehicle to another at the intersections. The routes followed by each vehicle are fixed and so are the itineraries of the cargoes to be transported. Load capacities, operating cost, and travelling times between intersections for each type of vehicle are constant. Likewise, the service and loading times for each type of vehicle at a given intersection are constant, except when delays due to congestion occur. The purpose of the simulation is to find out how well the system is integrated, how the services mesh, where congestions occur and how effective the particular types of vehicles used are on that part of the system where they are deployed. The strategy of simulation is characterized by; 1) cycles of discrete model real time intervals, during which cycles the situation at each intersection is reviewed to find which vehicles may be dispatched and which vehicles may be admitted. 2) a cargo labelling system, the labels indicating the itinerary to be followed, and the types of vehicle to be used on each route leg. 3) a vehicle labelling system, the labels stating the route schedules, which labels are compared with those of the cargoes to determine which cargo should be loaded or offloaded. 4) a sorting system at the intersections to form queues of vehicles and accumulations of cargo. The efficiency of the system is measured by the cost and the elapsed time for processing the cargoes from origin to destination, and the utilization and load-factors of the vehicles.

1Fa. 1. An Application of Operations Research to Municipal Planning: Some Fiscal Aspects of Land Use Planning, MAJOR M. J. AGNEW, *Hq. USAF, Washington, D. C.*, and CAPTAIN M. H. ALEXANDER, *Hq. AFSC, Andrews AFB, Md.*

This paper is a report of a graduate research project at Case Institute of Technology, Cleveland, Ohio, during the spring of 1963. The project was directed at making an application of Operations Research to municipal planning. Mayfield Heights, Ohio, a city with 15,000 population in the Cleveland Metropolitan area was used as the specific area of investigation. The problem as finally defined was to determine the impact of various land use patterns on the capital and operating budgets. The conceptual model and methodology used in solving the model are discussed initially. The detailed research and analysis of all city operating departments and income producing processes needed to develop a total system concept in the simulation are reviewed. Decision Flow Diagrams developed for this study served as the basis for integrating the actual operating procedures into a computerized simulation model, and data from the previous five year period was used to test model adequacy. Subsequently, three land use patterns reflecting possible city growth were developed with the city planners and these served as the input for analysis of growth in a future 20 year period. The paper reports briefly on the results of the research and discusses the validity of extending this type of analyses in the general planning process.

* **1Fa. 2. Operational Research in the Scheduling of Fertilizer Production at Cominco,** J. E Roberts, *Research and Development Division, The Consolidated Mining and Smelting Company of Canada Limited. Trail, B. C.*

Although feasibility studies of the scheduling of fertilizer production using linear programming methods began at Cominco in 1957, it was not until a suitable computer became available in 1961 that the work accelerated and has since been brought to the pay-off point. The paper outlines the scheduling problem and describes the methods used to solve the resulting large scale system of linear constraints with a computer of limited memory capacity. Some of the problems of implementing the results of the work are discussed and examples of applications and pay-offs are given.

1Fa. 3. Optimum Safety Stock in a Coal Ordering Problem, D. K. A. Gillies, J. G. C. Templeton, and W. H. Winter, *Operations Research Group, The Hydro-Electric Power Commission of Ontario, 200 Kipling Avenue South, Toronto, Ontario.*

Ontario Hydro generates electric power at three coal burning thermal generating stations, one small nuclear station, and many large and small hydraulic stations. The coal burnt at the three coal-burning stations is delivered by ship during the lake shipping season. The coal requirement is uncertain because of uncertainties in (1) the total energy requirement of the system; (2) the amount of water available to the hydraulic stations; (3) the number of generating units which may be out of service; and a number of other minor variables. We have an inventory problem with uncertain demand, long lead time and high stock-out costs. The coal-ordering problem is set up as a two stage decision problem to minimize the expected total cost of coal, carrying charges, interconnection energy and possible shortages. Numerical solutions have been obtained.

† **1Fb. 1. Requirements of Users of Scientific and Technical Information,** Charles M. Stearns, *Office of Technical Services, Department of Commerce, Washington, D. C.*

Efforts to date to define user needs, so as to have criteria by which to judge the performance of various information-handling systems, have produced little useful understanding. These efforts have, however, elucidated some reasons for their failure; as usual, hindsight makes some of these look obvious: (1) Different users have an enormous variety of needs. (2) Single users have an enormous variety of needs at different times. (3) Personal estimates of need appear (as usual) insusceptible to objective analysis. For these reasons, (4) Neither "need" nor "information" have ever been quantified. Current inability to measure need is made serious by the fact that even crude market-place evaluation of information services, the only evaluation which can be taken seriously to date, is going by the board with increasing levels of government subsidy of information processes. What is needed, it seems, before operations research or any other technique becomes useful in this situation, is some way of identifying at least classes, if not spectra, of both need and information; these must have sufficient universality to permit quantitative evaluation of the capability of competing systems to match the two. Examples will be given of approaches to the classification/Quantification problem here posed, and a few caveats (among them the requirement to recognize that the most intense needs for information are probably so intense precisely because of the improbability that any economically justifiable system can satisfy them) will be offered.

*** 1Fb. 2. Information Retrieval Problems in the U. S. Patent Office,** MR. EZRA GLASER, *Assistant Commissioner, U. S. Patent Office, Washington 25, D. C.*

Following a brief statement of the nature of patent search, an account will be given of some technical aspects of the research program in the U. S. Patent Office. The present system of measuring the "quality" of patent adjudication will be described, with particular attention to the ability of the system to measure the effects of introducing advanced search facilities or conventional reclassification of the patentable arts. Some formal models will be sketched which are designed to facilitate analysis of the patent adjudication process and to study the search of literature. Finally, references will be made in the use of recursive models for characterizing and evaluating large scale search and retrieval systems.

1Fc. 1. Queueing in Series-Parallel Networks, HENRY D. FRIEDMAN, *Applied Research Laboratory, Sylvania Electronic Systems, 40 Sylvan Road, Waltham 54, Massachusetts.*

A tandem stage system has n stages $A_1, A_2, \cdots, A_n$ in series, where stage A_i consists of m_i servers or channels in parallel, each using constant service time s_i. Customers arrive at the first stage and proceed through one channel of each stage on a first-come, first-served, unlimited queueing basis. For any sequence of customer arrival times, the time spent in the system by each customer is independent of the order of the stages. This permits rearrangement of the system to satisfy other conditions without changing the delay statistics. It also follows that certain steady-state and time-dependent problems in a tandem stage system involving waiting time, mean queue length, and busy period can *for any interarrival distribution* be reduced to corresponding problems for a system of fewer stages, possibly a single stage. When all $m_i = 1$, and one of the servers uses variable service times which always exceed the constant service times of the other $n-1$ servers, then the result still holds, and problems for the tandem server system can always be reduced to single server problems.

1Fc. 2. Multi-Channel Queueing with Periodic Service Interruptions, JOHN J. COLEMAN, and T. P. GIAMMO, *Space Technology Laboratories, Thompson Ramo Wooldridge, One Space Park, Redondo Beach, California.*

This paper investigates the problem of servicing a finite population by means of a multiple-channel service unit that is only periodically available. Equations are derived that govern the behavior of the system. Extensive analysis is done for the cases in which the number of channels is relatively small and again for the cases in which the number of channels is relatively large. On the basis of this analysis, approximations are developed to cover the entire range of service channels. A computer method of solving the exact equations is also given and comparisons are made with the various approximations by means of a few examples. The analysis of periodically interrupted service has many practical applications, both military and non-military. Although this investigation was developed for evaluating the effect of periodically interrupted service on missile readiness, it has obvious applicability to such problems as machine repair, communication, transportation, health systems, etc., where multichanneled service might be periodically scheduled while demands for service remain randomly distributed in time. Application of the same approach can be made to the inverse problem of periodically interrupted demand distributions for constant and/or varying numbers of service facilities.

1Fc. 3. Tandem Queues with Dynamic Priorities, ANDREW GRINDLAY, *Assistant Professor, University of Western Ontario, School of Business Administration, London, Ontario.*

The purpose of this study was to investigate the behavior of tandem queueing systems with due-date-like priorities. It fits into a group of studies which are aimed at exploring various job-shop sequencing rules, of deterministic and stochastic systems. The systems studied in this investigation consist of a series of work centers arranged in tandem such that when a job arrives at the system it immediately begins receiving service at the first center if that center is unoccupied; otherwise the job joins a queue comprised of other jobs also awaiting service. After receiving service at the first work center, the job proceeds to the second where, if the center is unoccupied, the job begins receiving service immediately; otherwise it joins the second queue. The same procedure is followed at all centers in the system. A job arriving at the system has associated with it a due time which is the time by which it must complete service in the system to avoid being considered tardy. The difference between the job's due time and its time of arrival is its urgency number, these numbers being used to separate the jobs into classes. For each job, the flow time is the time to elapse from the job's arrival at the system until its completion. Hence, associated with each urgency number is a flow time frequency distribution. The main distinguishing feature of the systems studied is the manner in which the jobs waiting for service are ordered in the queues. When any center completes service on a job, the job to receive service next is the one in the queue at that center that has the earliest due time. Thus the term "dynamic priorities", because the longer a job waits in a queue for service, the less the likelihood that a later arrival will precede it. Two hypotheses were tested, both pertaining to a tandem system in which queue discipline is governed by dynamic priorities, arrivals form a Poisson process, and service times are exponentially distributed. The first hypothesis states that the dynamic priority flow time distributions for the various urgency numbers are separated from each other at their upper tails by horizontal distances equal to the differences between their respective urgency numbers. The second hypothesis states that these dynamic priority flow time distributions are separated at their upper tails from the flow time distribution for a similar system using first-come, first-served queue discipline, by horizontal distances equal to the differences between the mean of the urgency number distribution and the respective urgency numbers. To test the hypotheses, systems of the type described above were simulated using the I.B.M. 7090 computer at the Western Data Processing Center. The results provided strong support for both hypotheses. Additional runs of the simulator were conducted to determine if the hypotheses could be broadened to include other systems. The hypotheses were supported for tandem systems with Poisson arrivals and constant service times and, with small modifications, for systems with constant arrivals and exponential service times. Of interest also was the rate at which the dynamic priority flow time distribution curves converged to their asymptotes. An empirical formula was found that permits estimates pertaining to this rate to be made.

1Fd. 1. Adaptation of an Existing Naval Proximity Fuze to Supersonic Targets, R. D. WILMOT, *1386 Gibson Avenue, Ottawa Ontaria.*

Test Firings of proximity fuzed rounds against a stationary target were examined with a view to extending its effectiveness against supersonic threats.

1Fd. 2. Some Comments on the Lanchester Theory of Combat, E. M. DURSTINE, *The Mitre Corporation, Bedford, Massachusetts.*

The purpose of this paper is to discuss some implications of two well known results in the Lanchester theory of combat. In the first of these, a deterministic model of battle with the possibility of reinforcements being introduced at a constant rate is considered. The formal solution to this problem is easily obtained. Slight rearrangements of the equations involved allow a direct comparison of this case with the simpler case where no reinforcements are considered. It is thus seen that the ability to reinforce is directly analogous to a reduction in the initial force strength of the enemy. In the second case, a probabilistic model of combat is considered and manipulated to give first order differential equations in the expected size of each force remaining at any time. This result was obtained by ISBELL and MARLOW (Naval Research Logistics Quarterly, 1956). These equations, though solvable in theory, are not practical to solve for any but very small forces. They are of considerable interest, however, in their similarity to the classical deterministic Lanchester equations, differing only by an additive term. Comparison of the solutions to these equations for small force size with the results of the deterministic Lanchester equations serves to indicate the accuracy lost in using a deterministic rather than a stochastic model.

1Fd. 3. The Distribution of Rounds Fired in Stochastic Duels, CLINTON J. ANCKER, JR., and A. V. GAFARIAN, *Systems Development Corporation, 2500 Colorado Avenue, Santa Monica, California.*

This paper continues the development of the theory of Stochastic Duels to include the distribution of the number of rounds to a kill. This distribution is principally of interest in estimating stock levels and resupply requirements in appropriate combat situations. Most generally, the duel between two contestants who fire at each other with known, fixed kill probabilities is considered. The time between rounds fired may be either a continuous random variable or it may be fixed. These two cases are treated separately. The number of rounds available to each contestant at the beginning of the duel may be limited and is a discrete random variable. Besides the distribution, the first two moments and the right tail are obtained. In addition to general results, special cases and specific examples are worked out.

1Fd. 3. Some Discrete Processes in the Theory of Stochastic Duels, C. J. ANCKER, JR. *System Development Corporation, 2500 Colorado Avenue, Santa Monica, California,* and TREVOR WILLIAMS, *The Johns Hopkins University, Baltimore, Maryland.*

The duel in which the contestant on each side has a fixed kill probability and a random (continuous) time between firings has been previously considered. By limiting the time between rounds to a constant, certain situations in which strong interactions occur have been investigated. The models investigated here are (1) the fundamental (one versus one) duel in which firing times are fixed and their ratio is a rational number; (2) the duel with displacements in which two contestants fire simultaneously at fixed intervals and a near miss causes a contestant to displace (and lose a firing turn); (3) multiple duels in which two versus one or two versus two fire simultaneously at fixed intervals and (4) the cluster duel in which there are several contestants on each side and firing is simultaneous. In the first three the probability of a given side winning is obtained. In the last, the probability of m contestants on the other side at a single firing is derived.

1Fd. 4. Operations Research Techniques in Radiological Civil Defense, F. LEMUS and J. T. RYAN, *Operations Analyst, Research Triangle Institute, P.O. Box 490, Durham, North Carolina.*

This paper deals with the application of a variety of techniques of Operations Research to the analysis of radiological civil defense systems. The paper introduces the layman to some terminology on the effect of nuclear weapons. It describes the various factors affecting radioactive fallout, and explains how these factors can be used to formulate mathematical models to yield measures of effectiveness. A discussion of appropriate measures of effectiveness (total dose, in rems; equivalent residual dose, in rems; and number of fatalities) is followed by a summary of the analysis of results from one concrete example, where statistical techniques of analysis of variance and multiple regression are used to uncover the behavior and effect of shelter system factors. The example shows the relationship between these two techniques and explains how, in the absence of randomness, the validity of the conclusions rests exclusively with the assumptions in the model. The use of other methods of Operations Research in civil defense are discussed in detail: the application of linear programming to deduce the number of casualties, one of the best measures of effectiveness; the use of minimization techniques to derive optimum strategies for decontamination and evaluation operations; and the application of allocation theory to various civil defense problems.

2Fa. 1. Maintenance Planning for the Minuteman Weapon System, R. R. CALDWELL and R. A. CAWBY, *The Boeing Company, Seattle, Washington.*

The Minuteman Weapon System consists of Wings of 165 remotely located sites containing complex electric-electronic and mechanical equipments which are maintained from a central support base by the dispatch of repair teams. Of the 165 sites, 150 are unmanned. To provide maintenance, failures must be detected and reported to the manned control centers; preliminary fault identification made; teams made up of personnel, test sets, and spares dispatched; faults isolated on site; and failed components removed and replaced. To ensure development of an effective maintenance program, planning was conducted during the system design phase using predicted equipment failure rates and detailed analysis of all maintenance operations. The objective was to obtain a balance between the cost of the maintenance activity and the equivalent cost of missile downtime. General concepts such as lengths of work day, dispatch rules, and transient effects of weather and week ends were investigated with a digital computer simulation. Fault detection, accomplished by a combination of remote continuous monitoring, remotely commanded tests, and on-site tests, was designed to minimize undetected site downtime and detection system cost. Failure mode analysis provided the basis on which to optimize test frequencies and provide appropriate repair team responses. (Because of ambiguity in remote fault identification, it is frequently necessary to dispatch a repair team made up to repair the most probable failure and follow it with a second trip if necessary). Quantities of support elements were provisioned on a cost-effective basis by minimizing the costs of support elements and site downtime through use of a queueing model based upon random demand by the failing sites and constant holding times.

* **2Fa. 2. Scheduling of Preventive Maintenance on the Mid-Canada Line,** T. A. Ewashko and R. L. Baglow,

The advent of high-speed, immediate access computers has found wide application in the techniques of Operational Research. This presentation describes a computer technique used to optimize the helicopter operation on a section of the Mid-Canada Line in terms of the flying hours of the helicopter. The helicopter is responsible for positioning maintenance crews at isolated sites of the section in order to execute a specified maintenance program. Many of the helicopter jobs involve the same crew, and cannot begin until the crew has completed its assigned tasks. However, we are at liberty to choose the jobs in any order we wish. Techniques such as linear programming are not applicable, since the costs of the jobs are not fixed, but rather are a function of job order. It can be shown by information theory that a programming technique called "Backtrack" is the most efficient approach to this type of problem. With this technique a systematic search is made through the set of job permutations to determine the schedule which best satisfies the given function. By a judicious choice of constraints, this technique will converge rapidly towards the optimum schedule. The feasibility of using "backtrack" to select a schedule for the helicopter, and the problems encountered in its approach will be discussed in the presentation.

* **2Fa. 3. An Operational Research Study of the Determination and Prediction of Satellite Orbits,** E. C. Kehayas, *of H. S. Gellman & Co. Ltd., Toronto, Ontario* and J. L. Hudson, *Directorate of Systems Evaluation, R.C.A.F., Ottawa, Ontario.*

In modern space operations it is becoming increasingly important to be able to determine accurately the orbits of satellites and predict where any given satellite will be at any given time in the future. The degree of accuracy required becomes higher as the space operations become more complicated. Anyone who has followed the "man in space" programmes will know that an essential part of each operation in these programmes was the detection and tracking of the space vehicle by a network of ground based sensors. For every space vehicle placed in orbit the series of measurements provided by the sensor network is used to derive estimates of orbital elements or position and velocity vectors at a specified time. It is obvious that the accuracy with which an orbit can be determined will be a function of the factors associated with the sensor network. These factors include the type of measurements made by each sensor, accuracy of measurement, frequency of measurement, distribution of sensor positions and many others. To establish the relationships between these factors and the accuracies of orbital parameters is a typical military operations research problem. The present paper gives an account of a method currently being used to relate the accuracy of orbital determination to the requirements of a sensor network, describing also some typical results and deductions which have been obtained.

* **2Fb. 1. Techniques for Associative Information Retrieval,** VICENT E. GIULIANO, *Operations Research Section, Arthur D. Little Inc., 35 Acorn Park, Cambridge 40, Massachusetts.*

At present, the operation of large-scale mechanized document retrieval systems requires experts who are thoroughly familiar with the contents of the collection at hand, and who intermediate between users of the system and the mechanized searching apparatus. There is considerable evidence that many of the limitations of performance, size, and cost of existing systems are due to the difficulty of conducting this function for large document collections. This paper is concerned with the application of statistical association techniques to the design of document searching systems. The techniques are based on the use of certain readily computed measures determined by the patterns of usage of index terms within a given document collection. Computed association measures are influenced by frequency of usage of index terms in a given document collection, and by the patterns in which index terms are used together and therefore correlated. Through use of association measures, retrieval systems can be designed which automatically reformulate a search request in several alternative modes which are influenced by frequency of usage of index terms in a given document collection, and by the patterns in which index terms are used together and therefore correlated. Through use of association measures, retrieval systems can be designed which automatically reformulate a search request in several alternative modes which are synonymous with respect to the given data collection. The system can find documents satisfying the topic of inquiry, even if they are indexed and requested with different terms. A second benefit is that the output of an associative system is not a given set of documents, but a ranking of all documents in the collection in order of a decreasing measure of computed relevance. Some of the techniques developed in the course of the writer's research will be discussed in detail, and examples will be given of machine-generated association lists.

*** 2Fb. 2. Man-Machine Interaction in Information Retrieval,** CHARLES W. ADAMS, *President, Charles W. Adams Associates Inc., Bedford, Massachusetts.*

In many situations, successful retrieval of desired information involves selection processes based on "judgments". These situations arise when the information sought cannot be described in advance by manageable numbers of sufficiently exact criteria. Indeed, the user often hardly knows what he does want until he examines some of the alternatives available. The usual approach to the problem is to give the user a broad range of choice, from which he is to make the final selection by himself in a direct fashion. Another promising technique is to include the user in a continuing selection process—allowing him to sharpen, loosen, or shift his criteria as he sees the results he is achieving. Time-sharing techniques and display devices are rapidly evolving; these make man-machine interaction increasingly attractive in terms of cost, ease of development and ease of use. The paper will describe recent experience in both planning for and use of many of these devices and techniques.

2Fc. 1. A Queueing System with Alternating Priority, B. AVIITZHAK, *Technion, Israel Institute of Technology, Israel,* W. L. MAXWELL, and L. W. MILLER, *Cornell University, Ithaca, N. Y.*

For a service facility serving more than one class of customers a problem arises as to the order in which customers should be served, (i.e. the priority rule). A typical example is a manufacturing facility which produces two products to meet a random stream of incoming orders. In this paper the alternating priority rule (also known as the "zero switch rule") is introduced and investigated. Two classes of customers are served by a single service facility. Customers of class $i(i=1, 2)$ have priority over customers of class $j(j=1, 2; j\neq i)$ whenever a class i customer is in service. When the service facility is idle, the first arriving customer enters service and acquires the priority right to customers of his class. Within classes the "first come first served" rule is observed. Customers arrivals are assumed to be Poisson and service times are assumed to be arbitrarily distributed independent random variables. The steady state queueing times densities are formulated by the use of a special mathematical procedure and the expected queueing times and queues' sizes as well as the first two moments of the busy periods are obtained in terms of the basic parameters of the arrivals and service times distributions. All the results are related to the case where there are no setup times in switching from one type of customers to another. The alternating priority rule is compared to the "head of the line" and the FIFO rules with respect to expected queueing times and queue sizes. The last part of the paper discusses the possibilities of extending the suggested rule to the cases where there are more than two classes of customers involved and switches of service are penalized by setup times and costs.

2Fc. 2. On Jockeying in Queues, ERNEST KOENIGSBERG, *C-E-I-R, Inc. 345 Howard Street, P.O. Box 3243, San Francisco.*

There are numerous queueing situations in which those awaiting service may be allowed to make choice which affect the time spent in the service system. In such cases, it should be possible to formulate a "strategy" for customers to follow in order to optimize a given parameter. A whole class of queue problems which involve "jockeying" can be regarded in this way, but has so far received little attention. Jockeying can be described as the movement of a waiting customer from one queue to another (of shorter length or which appears to be moving faster, etc.) in anticipation of a shorter delay. We have so far considered just a few of the various possible jockeying disciplines in two server systems with heterogeneous "exponential" servers and Poisson inputs. As a basis for comparison, we first treat the heterogeneous server problems where arriving customers join the shorter of two independent waiting lines and are not permitted to jockey. The same problem is then considered, allowing instantaneous jockeying from the longer to the shorter line when the difference in line lengths exceeds one. The results, in terms of expected line lengths and delays, are identical to those obtained by GUMBEL for heterogeneous servers fed from a single queue. When the same problem, with customer preferences for a specific line, is considered the results are identical to those of KRISHNAMOORTHI. It is important to note that in these two problems the slower server has a larger throughput than might be expected from the classical theory. In other words, the slower server acts as a trapping state. In the last problem treated here, customers join a preferred line and may jockey at a rate proportional to the line lengths. The results show that the over-all service is better than the alternative (two independent single server queues).

2Fc. 3. Markov Chain Analysis of a Sorting Machine: Formulae and Illustrative Applications, JOEL LEVY, *National Bureau of Standards, Room 140, North Building, Washington 25, D. C.*

A possible automatic sorting machine which can be used simultaneously by several clerks is studied. Information on the behaviour of the machine is given as a function of parameters describing the inflow of material to be sorted and describing the machine. An illustration is given of how decisions based on the information obtained can improve machine performance.

2Fd. 1. Fatefulness: A Measure Deserving Recognition, JOHN COYLE, *4706 North 36th Street, Arlington 7, Virginia.*

The inevitability of change beyond present concepts and the arbitrariness of cut-off dates for design based on forecast trends weaken the credibility of many types of planning objectives. In particular a well-defined objective promotes economy by channelling effort but at the expense of greater costs to shift to new objectives when the original conception is overtaken by events. Military procurement, conservation, and urban zoning and public works are seen to illustrate certain similar types of conflict between the immediate and the long term perspective. Investigation can suggest measures of effectiveness and policy formulations to better protect the long range policies from too wishful or narrow a concentration on the business at hand. A property of decision commitments which significantly influences potential conflict of purpose with long range objectives is fatefulness. This is defined as the range between maximum net loss or net gain, measured either relative to other commitments or absolutely, in terms of an overall net worth. While extremely difficult to measure objectively, even a rather rough judgment of fatefulness can be useful: to qualify measures of effectiveness of single fateful choices being compared with more cautious stepwise, or mixed, solutions and as a heuristic for suggesting expedients to diminish fatefulness, and thus to relieve parochial enterprise from the burden of having to choose between being indecisive or overbearing. One such expedient would be the discrimination in information handling between consensus "clones" of re-stated "common knowl edge" and independent observations of fact.

2Fd. 2. Forecasting: A Pitfall in Military and Civilian Long Range Planning, HAROLD A. LINSTONE, *Senior Scientific Advisor, Corporate Development Planning, Lockheed Aircraft Corporation, Burbank, California.*

Forecasting, a highly useful tool in short range planning, loses much of its value in long range planning as the analysis must focus on the uncertainties. The requirement for decision making under uncertainty poses problems to the defense planner analogous to those experienced by the businessman. This paper discusses the introduction of subjective probabilities—the likelihood of recession in the calculations of the businessman and of a technological breakthrough or a specific type of limited conflict in the planning of future defense force structures. Analogous aids in assessing alternative courses of action are considered for improved long range planning.

2Fd. 3. Concepts for Mission and System Planning, NORMAN HITCHMAN, *Technical Military Planning Operation, General Electric Company, 735 State Street, Santa Barbara, California.*

During the seven year span of its history, GE/TEMPO has been increasingly concerned with the need to: (1) identify the fundamental processes of planning, and (2) develop practical tools to implement these processes. One of the key components of the planning process is environmental research, which may be defined as the study of basic forces whose interaction forms the context of world affairs. For purposes of long range national planning, aspects of political, military, economic, social, geographic and physical forces are involved. By structuring and documenting the environment, high confidence missions or objectives can be determined. A test for the feasibility of various hardware devices for the fulfillment of these missions then can be performed. From among the feasible hardware solutions a test for practicality (such as cost-effectiveness), indicates the preferred solution. This paper will present a planning structure and models which will show: A common planning structure which is useful for solving problems at all levels, and a method for testing the feasibility of various hardware devices for satisfying missions.

3Fa. 1. Strategies of Speculation in the Stock Market, J. T. ROSS JACKSON, *Operations Research Group, Case Institute of Technology, Department of Management, University Circle, Cleveland 6, Ohio.*

A fairly simple random walk model of stock price movement is used to derive optimal decision rules for investment of funds in the Stock Market. The possible strategies which are considered for each stock include: (a) Purchase and retention, (b) short sale, (c) purchase of options (put, call, straddle), (d) sale of options, (i) if stock is owned, (ii) if stock is not owned, (e) no position. The problem is seen as one of continual shifting of funds to those investments which have the greatest expected return. The effectiveness of the decision rules is compared to that of alternate policies for a random selection of stocks during the period 1960–1963. The decision rules lead to a significantly greater return and provide some rather interesting and surprising insights into the nature of stock investments.

3Fa. 2. Stock Exchange Volume as a Stochastic Process, HAROLD GREENBERG and IRWIN GREENBERG, *College of Engineering, New York University, Department of Industrial Engineering and Operations Research, New York University, New York 53, N. Y.*

The daily volume of stock transactions on the New York Stock Exchange is studied as a stochastic process. The day-to-day totals are shown to follow an autoregressive scheme. The order of the scheme is found; this determines the persistency of dependence between a day's volume and those of the previous days'. The equation describing the scheme is then presented together with the variance of the error term.

3Fa. 3. Implementation of Operational Research—A Problem in Sociology, JOHN W. ABRAMS, *Department of Industrial Engineering, University of Toronto, Toronto 5, Ontario.*

The problem of securing successful implementation of operational research is shown to be that of introducing change into a social system. It is shown how this problem can be generalized into a mathematical model, whose parameters are those of the system under study. It is seen that results of implementation involve both the structure of the system and the output. Many operation research studies, however, either neglect the former or consider it in terms of the social system of the scientist rather than of the system under study. It is shown that successful implementation in these circumstances is merely fortuitous. More frequently the result is either partial acceptance—which may lead to the adoption of procedures which are markedly sub-optimal—or to rejection. Such lack of acceptance is well-known and attributed to lack of appreciation and lack of communication. It is demonstrated that these two factors are merely manifestations of social interaction and thereby governed by the rate by which a social system can be changed, which rate is far slower than that of technology. It is held that sociological factors must be included in operational research models and that the resultant complication will be more than compensated by more extensive acceptance with a consequent increase in amount of implementation. Illustrations are given.

3Fb. 1. New Dimensions in Information Retrieval Systems, HENRI L. BEENHAKKER, *Stanford Research Institute, Menlo Park, California.*

Information retrieval systems form a part of data processing systems. The best strategy for the design of an information retrieval system is obtained by considering all the component activities of a business concern. In other words, the design of an information retrieval system should be incorporated in the design of the data processing system of the entire firm. Data processing is described as the mathematical techniques by which operational data are handled and the development of the procedures for the realization of the functional objectives of a firm. The most important potentialities of computers and their peripheral hardware introduced in a data processing system are discussed. Both centralized and decentralized management systems are possible with a computer. The motivations for data processing in industry are described. Long-range benefits of a data processing system are compared with short-range benefits. A quantitative approach to the planning task of a firm is recommended. The reasons for the application of quantitative models are discussed. It is suggested to introduce a management information system which can be looked upon as a formal structure through which decisions are translated into action and which provides feedback to the decision maker. Problems in introducing data processing systems are discussed. The end of the paper suggests an outline for the actual programming of a firm.

3Fb. 2. A Computer-Generated Thesaurus, P. B. HENDERSON, JR., *Advanced Data Systems, Westinghouse Electric Corp., 15 West 3 Gateway Center, Box 2278, Pittsburgh 30, Pennsylvania.*

In many information retrieval applications, the first objective is to retrieve references to items which are responsive to the search specifications. After review of the reference list and abstracts, the documents themselves are retrieved. The basis for classification of items for reference retrieval is typically a dictionary or thesaurus of descriptive words and phrases. This paper concerns a computer-generated thesaurus developed by Westinghouse Electric Corporation for a corporate-wide technical reference retrieval program. The Westinghouse Reference Retrieval System is completed and operative on the IBM 7094. Effective and economical retrieval of references from large files (>100,000 items) requires that substantially improved techniques be provided in six areas: 1) Classification specifications must be compatible with a significant portion of present classification data. 2) Differences in language and changes in vocabularies must be routinely accommodated. 3) Extra descriptive terms—such as generic and hierarchical associations—must be uniformly and consistently imputed when they are implied. 4) Data representation for both storage and search must be efficient and must accommodate a high degree of complexity and detail. 5) The questioners must be provided a direct and understandable means of communicating their queries. 6) A choice of output data must be provided. For economic reasons, it was essential that the cost of classifying, storing and retrieving the data not be increased by the introduction of these improvements. A general system, suitable for adaptation to other classes of items, was needed to minimize system design and programming costs. The first three goals were attained by modifying the classification process and by introducing the use of the computer for the generation and maintenance of the dictionary. It is no longer necessary to impose code book or thesaurus control on the contributor. Within each of several agreed descriptive topics of discourse the classifier is free to use any desired term, code or phrase in English or any other language which can be represented in the standard character set. The dictionary control process includes the recognition of synonyms and the imputation of any desired generic and hierarchical terms. At present, an average of about twenty terms per item are obtained from the classifier and an additional twenty from the imputation process. The use of the computer permits the routine recognition of more than 150,000 raw input terms and provides for their transformation into a controlled vocabulary of about 20,000 terms. The ease of accommodating existing glossaries and thesauri, of introducing new terms as they appear in technical use and of systematically imputing implied terms and the ability to absorb existing classification data with minimal reprocessing indicate that this approach is both technically and economically superior to the conventional thesaurus control concept.

3Fb. 3. Dial-A-Document Central Libraries, WILLIAM L. ALDEN, *President, Automation Management Inc., Westboro, Massachusetts.*

L. B. HEILPRIN has developed data and formulae indicating the savings of retrieving and copying a document to give to a user of a library upon request. The cost of circulating a several-page article is greater than copying it and not having the copy returned to the library. This paper suggests the further economies, in money and time, of users at remote points receiving their copy by means of facsimile (combined electronic transmission and duplication). The far-reaching implications of one or more central technical libraries or "publishers" covering all or sections of the North American continent are suggested. The reported facts and logic can be used in determining the desirability and design of a centralized information retrieval system for an organization.

3Fc. 1. The Integration of Human and Machine Performance, ERIK A. R. HALDANE, *3327 "N" Street, N.W., Washington, D. C. 20007.*

Research on Army problems may be assigned priorities and effectively organized around the concept of man-machine systems. Such systems, or complexes, may be identified, designed and studied with respect to their properties, functions, and performance in specific environments. They have observable and measurable capabilities and vulnerabilities, are susceptible of progressive improvement and degradation, and interact with competing enemy systems as well as the environment. The machine components of these complexes may be advantageously viewed as "prosthetic" devices enhancing the sensory, motor, or cortical capacities of the associated humans. Multidisciplinary analysis of the theoretical and operational characteristics of selected man-machine systems would, in the authors' judgment, provide for the orderly accumulation of knowledge to assist in the use of resources and the organization of forces for the accomplishment of future military—or other definable—objectives. An example of this type of analysis will be provided.

3Fc. 2. Control Theory in Nonstationary Ecosystems, MARK ALFANDARY-ALEXANDER, *University of Pittsburgh, Visiting Professor, Research Analysis Corp., 6935 Arlington Road, Bethesda 14, Maryland.*

The principles of feedback control are of significance in biology and are becoming increasingly important in engineering, management, economic, and statistical processes. A common feature in these systems is the necessity of control action under various conditions of uncertainty regarding the system, its environment, and the relevant interactions. Control decisions are to be made in situations where the process transitions are only partially known, in cases where measurements of the current states of the ecosystems are imperfect, and, in some instances, where the criteria of merit are not even characterized. Developments in control theory are presented as means of transforming these problems into more tractable forms.

3Fc. 3. Towards a General Theory of Systems—Models of Subsystems' FRANK BENSON and MEHMET GUREL, *Case Institute of Technology, Cleveland, Ohio.*

Many attempts have been made and will continue to be made to build a general theory of systems. Most of these attempts are characterized by an intention to achieve complete generality. The aim of the work reported in this paper was more modest. Much has been learned about man-machine systems by the use of OR models. However, progress has been achieved by isolating particular subsystems for which it was possible to design models with the desirable property that the derivation of solutions was a feasible task. As a result of this, the theory of OR is fragmentary. As a preliminary step to building a more comprehensive theory of man-machine systems, we have investigated assemblies of just two subsystems for each of which a known model type exists. There were two purposes in mind: to discover whether the combination of model types would produce new and more general model types and also to investigate the interactions between subsystems. The first purpose proved to be difficult of achievement, because we chose examples for which we could not derive the solution. The study of interaction, however, proved to be interesting even with very simple systems. A drastically simplified model of electricity supply is described in detail to illustrate the difficulties which can arise when two connected subsystems are under the control of different decision makers.

3Fd. 1. Cost Benefit Analysis and Project Evaluation, JOHN S. MACDONALD, *Room 2731, United Nations, Box 20, Grand Central P.O., New York, N. Y.*

Cost benefit analysis, while it yet lacks a coherent formulation, is emerging as an increasingly versatile technique. It already represents the best available approach to reconciling decision making at the macro and micro-economic levels. The technique has an established use in analysing projects which are undertaken for direct economic gain, (non welfare projects). Its use is being extended to include appraisal of projects involving welfare economics; i.e. where direct economic gain must be reconciled with the collective economic interest. The difficulties in using the technique for both types of problem are discussed. A description of the Discounted Cash Flow Rate of Return method (DCF) and the concepts of Opportunity Costing and Shadow Pricing among others are given. The problem of translating economic and social welfare benefits into units of measurement comparable to the cash equivalents or material balances used in economic models is presented. The background for the discussion is a varied one and references are made to the differing types of economy throughout the world. The application of the methods in handling various types of problems is discussed. These include such projects as Irrigation and Reclamation, Air Pollution Control, Health Urban Transit, Highways and Transportation Networks, Recreation, Housing, Education and Depressed Area Development.

3Fd. 2. Planning, JACQUELINE ANDERSON, *Operations Research Group Case Institute of Technology, University Circle, Cleveland 6, Ohio.*

Few attempts have been made to formulate a theory of planning. Among those that have been made, there is general agreement that planning is a type of decision making. There is disagreement on whether rational or scientific methods can be used to make these decisions. The controversy is a result of a fuzzy concept of what planning attempts to do and the difficulties involved in doing it. The unique feature of planning is the necessity for making simultaneous decisions in order to answer interdependent questions. Since the present mathematical techniques of scientific method allow optimization with respect to only one or two decisions, they are inadequate for planning purposes. However, scientific method as a way of conducting and solving problems is applicable and, in the end, logic is the basic tool for obtaining rational planning decisions. Planning faces other difficulties as a result of the lack of knowledge about the formulation of objectives and the generation of resources. In addition, the uncertainty of the future requires that planning be flexible and/or adaptive.

3Fd. 3. An Heuristic Approach to Corporate Planning by Aggregating Models of Business Functions, MARK E. STERN and BERNARD B. HANON, *New York University, Graduate School of Business Administration, 100 Trinity Place, New York 6, N. Y.*

Although mathematical models of many business functions have been reported, there is little evidence that a set of these models representing the functions of a given firm has been integrated into a meaningful, consistent, cohesive plan of business action. In other words, models giving local optima are numerous; however, the purpose of planning is to achieve global optima. After investigating the nature of planning, the concept of the planning audit, and the need to adjust the plan to a changing environment, the paper suggests by using several models as examples how intermodel linkages can be accomplished. Bayesian statistics and statistical control charts are introduced as a means of permitting management to ascertain to what extent current operations are consistent with planned results. Criteria for identifying "significant deviations" and their corresponding loss functions are established; a diagnostic approach to tracing deviations back to the pertinent subfunction is developed.

4Fc. 1. Model for Decision—A Method for Selecting R & D Efforts, MELVIN TANCHEL, *Technical Advisor, Directorate of Technology, Hq. AFSC, United States Air Force, Andrews Air Force Base, Washington 25, D.C.*

Our rapidly expanding technological base poses an enormously difficult problem to the decision-maker responsible for selecting technical efforts. Faced with a fixed or decreasing resource budget, it is indeed a difficult task to select which technical efforts to fund from the vast potential. This paper presents a technique to aid the decision-maker. By making use of known techniques of system cost/effectiveness analysis, we use a model to establish an orderly array of technical efforts. The paper describes the technique and discusses some of the values obtained by the use of the model. It points out that this technique is an aid to the decision-maker and not a replacement for him.

4Fc. 2. A New Weight-Setting Model for General Use in Evaluations, LEROY R. ROSEN, *Department of the Navy, Bureau of Ships, Washington 25, D. C.*

An investigation is made into the "Approximate Measure of Value" theorem and a proposed new theorem, both of which have been derived as an aid in determining the optimum set of weighting factors to be applied to problems requiring comparison of complex alternatives. The study discloses that the "Approximate Measure of Value" theorem is invalid, but that its deficiencies can be corrected through adoption of the new theorem.

4Fc. 4. POED—A Method of Evaluating System Performance, D. R. J. WHITE and D. L. SCOTT, *White Electromagnetics Inc., 670 Lofstrand Lane, Rockville, Maryland.*

* POED is an evaluation and decision technique which permits computing performance of a device, equipment, system, or system complex; compares and scores this performance against requirements or value judgements representing users' needs; and organizes results in a useful manner so that assessment of value is readily achieved. It is a basic ingredient for making decisions. POED permits comparing performance of dissimilar to competitive systems against several yardsticks representing different attributes of performance requirements. It also provides a means for determining sensitivity of a system to its constituents and for computing the confidence factor of results. Finally, POED provides a synthesis tool for optimizing systems in conceptual, design, operational, or retrofit stages. * Pronounced Po'ĕd: POED—*P*erformance *O*rganization for *E*valuation and *D*ecision.

4Fd. 1. Allocating Restricted Resources to a Project Network, DR. R. L. MARTINO, *Manager, Advanced Systems, Olin, 460 Park Avenue, New York 22, N. Y.*

Networks can be used to represent the activities to be performed in a project. Estimates of time and cost are used to establish possible project durations and to find the Critical Path or longest chain. However, the actual project duration and the possible job starting times are dependent on the resources available. In fact, after resource restraints are taken into account, a new critical path is often established. A technique has been developed for allocating resources in an optimum or leveled fashion. This method is applicable to a single project or to many projects simultaneously. The resources may be fixed, variable, or a combination of fixed and variable limits. There is no limit to the number of resource types, or the number of activities, that can be handled. The result of the allocation procedure is a scheduled starting time for each job, taking into account both the resources required and the resources available. The results of the calculation procedure may be further displayed on a time-oriented network to provide visual assimulation of the results. This paper will outline the resource allocation and scheduling procedure described.

4Fd. 2. On Expected Times for PERT Activities, KLAUS ABT, *U. S. Naval Weapons Laboratory, Dahlgren, Virginia.*

In order to study the relation between estimated and actual times for PERT activities, many of the U. S. Navy's completed networks, with a total of approximately seven thousand activities, were analyzed. The goal of this analysis was to improve the present time prediction procedure, which uses a prediction formula based on the assumption that the time estimates are beta-distributed. Extensive applications of multiple regression techniques showed that the estimated "most likely" time m of an activity has the highest prediction power for the actual time. In fact, a polynomial in m of second or third order, depending upon conditions, in many cases was found to be sufficient to predict the (logarithm of the) average actual time, or "expected time". The respective coefficients in the polynomials of a given order did not vary significantly between the systems analyzed. Also, the variability of actual times about their mean for given most likely times m showed a uniform pattern for all cases investigated. On the basis of these consistent results it is concluded that the prediction of expected times for PERT activities and their variances could be improved by using the established relations between estimated and actual times, provided that these relations are continuously verified or corrected as more networks are completed.

Society Affairs

THE ORSA COUNCIL MEETING

During the Society's Meeting in Seattle the Council met on May 6 and 7. At these sessions, the following items were reported and discussed:

1. W. Edward Cushen has been named a Contributing Editor of IAOR for the United States
2. Whether ORSA National Meetings should last two or three days was discussed. It was the sense of the Council that the length of a Meeting is a prerogative of the Meeting Chairman and Committee.
3. The presentation of papers at National Meetings and the publication of abstracts were discussed. It was the sense of the Council that the Meeting Chairmen and Committees should be guided by the Constitution and By-laws of the Society with respect to these matters.
4. The Council accepted the proposal of Ellis Johnson, representative to the AAAS, that the Society, in cooperation with TIMS, prepare a program for presentation at the December 1964 Meeting of the AAAS to be held in Montreal.
5. The Council voted to sponsor the Third International Symposium on the Theory of Traffic Flow, tentatively scheduled to be held in the summer of 1965 in New York. The Transportation Science Section will handle arrangements for the Symposium.
6. Martin Ernst has been named Chairman of the Program Committee for the IFORS Meeting to be held in the United States in the summer of 1966.
7. As of the end of October, the Society's paid membership numbered 3,693, and subscriptions to the Journal numbered 3,317.
8. The Membership Committee reported its nominees for full Membership in the Society. A list of the new Members elected is shown below.

ELECTED TO FULL MEMBERSHIP

NOVEMBER COUNCIL MEETING

Ayer, Franklin A.
Bolthouse, Anthony S.
Boose, James Arthur
Brevdy, June
Bullington, Edward W.
Christenson, Charles J.
Cole, Alexander T.
Curtis, Wesley E.
Dean, Richard A.
Driscoll, John J.
Eberhard, Robert A.
Fabrycky, Wolter J.
Farr, Edward C.
Fishburn, Peter C.
Frick, James W.
Gibson, John D.
Glick, Jerome M.
Good, Donald E.
Gorfinkel, J. Martin
Greene, Richard M.

Hall, James E.
Handa, Trilok N.
Hart, Alex L.
Heit, Paul
Heuston, Milton C.
Honerkamp, Donald L.
Hughes, Richard R.
James, Larry B.
Jamison, Sue Storer
Johnson, Albert M.
Kahle, Robert V.
Karl, Darrel J.
Karlik, Lubor J.
Kirk, Raymond L., Jr.
Krill, Arthur M.
Kurke, Martin I.
Larsen, James Walter
Lewis, Theodore S.
Ling, Rufus C.
Locksley, Norman
Marx, Henry Peter
Mathewson, Morley H.
McKenney, James L.
Mirasol, Noel Mario
Missler, Charles W.
Mobille, George Jack
Mohr, Edward J.
Muir, Donald E.
Nerenstone, Marc A.
Niland, Powell
O'Meara, Francis J.
Ortenburger, Leigh Natus
Payne, Wilbur
Roberts, John Edwin
Roeloffs, Robert
Rose, Richard H.
Rosenberg, Lloyd H.
Rothstein, Marvin
Rowen, John W.
Rubin, Milton D.
Samuel, Aryeh
Searcy, Wiley T., Jr.
Sessler, John C.
Seversky, M. D.
Shy, William H.
Singer, Arnold
Soriano, Abraham
Stahel, Hans W.
Stringer, John
Thompson, Wendell J.
Toellner, John D.
Torres, Jaime F.
van Gigch, John Peter
Ventura, E. M.
Wade, Peter F.
Weaver, B. D.
Wells, William J.
Whiston, William B.
White, Douglas J.
Wolfson, Milton L.

TREASURER'S REPORT

Santa Monica, California
March 3, 1964

Following is a statement of Cash Receipts and Disbursements of ORSA for the calendar year 1963. The report of the auditors accompanies this statement. A breakdown into three columns is used, with International Abstracts in Operations Research and the Bibliography Project receiving special consideration. The method of statement is on an explicit cash basis with major obligations listed by note.

The Bibliography Project is now completed. This effort was originally supported by the National Science Foundation. During 1963, all the support for the Bibliography Project was from ORSA funds.

John E. Walsh
Treasurer

AUDITOR'S REPORT

Baltimore, Maryland
February 25, 1964.

The Operations Research Society of America,
Baltimore, Maryland.

We have examined the statement of cash receipts and disbursements of The Operations Research Society of America for the year ended December 31, 1963. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying statement presents fairly the cash receipts and disbursements of The Operations Research Society of America for the year ended December 31, 1963.

LYBRAND, ROSS BROS. & MONTGOMERY

STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS

For the year ended December 31, 1963

	Regular	*International Abstracts in OR*	*National Science Foundation Grant Bibliography Project*
Receipts:			
Members' dues	$44,271	$11,164	
Subscriptions	32,186	14,679	
Advertising, less commissions	15,199		
Sales of back issues	5,092	32	
Royalties	3,978		
Interest	2,311		
Meetings, net	1,184		
Miscellaneous	889		
	105,110	25,875	
Disbursements, as annexed	84,869	33,792	$2,251
Excess of receipts over disbursements	20,241	(7,917)	(2,251)
Cash at beginning of year	55,227	25,885	200
Cash transferred in support of:			
I A O R	(1,395)	1,395	
Bibliography Project	(2,051)		2,051
Cash at end of year	$72,022	$19,363	$ -0-
Represented by:			
Petty cash funds	550	200	
Demand deposits	16,472	19,163	

	Regular	*International Abstracts in OR*	*National Science Foundation Grant Bibliography Project*
Deposits with federal savings and loan associations	55,000		
	$72,022	$19,363	
Portions of the cash balance are reserved as follows:			
Unearned subscriptions:			
Volume 12 to be issued in 1964	24,000		
Volumes 3 and 4 to be issued in 1964 and 1965		14,500	
Guarantee to publisher of the Society's series "Publications in Operations Research"	6,000		
Unpaid reimbursement vouchers and bills		500	
	$30,000	$15,000	

DISBURSEMENTS

For the year ended December 31, 1963

	Regular	*International Abstracts in OR*	*National Science Foundation Grant Bibliography Project*
Journal printing costs	$38,244	$17,587	
Editorial and other expenses	9,785	700	
Salaries and fees		7,957	$1,827
Managerial services	14,106	2,685	
Bulletin printing	4,609		
Publications in OR	4,245		
Printing and binding directory	3,394		
Travel expense	3,554	2,615	
Council and officers' expenses (Note)	2,143		
General Society expenses	1,806		
Lanchester Prize	1,000		
IFORS Dues	796		
Supplies, materials, etc.		1,331	224
Auditing	300		
Committee expenses (Note)	254		
Brochure on OR	146		
Equipment		899	
Mail list	369		
Miscellaneous	118	18	200
Total disbursements	$84,869	$33,792	$2,251

	Regular	*International Abstracts in OR*	*National Science Foundation Grant Bibliography Prpject*
Note: Details of council and officers' expenses and committee expenses are:			
Council and officers' expenses:			
Council	$248		
President	934		
Secretary	461		
IFORS Secretary	500		
	$2,143		
Committee expenses:			
Membership	$104		
Prize	100		
Sections	50		
	$254		

HAWAII MEETING: ORSA WESTERN SECTION

The Tenth Annual, First International, Meeting of the Western Section of the Operations Research Society of America will be held at Honolulu, Hawaii on 14–18 September 1964, and is being co-sponsored by The Operations Research Society of Japan. This meeting has three themes: (I) Uses of operations research (OR) in technical fields and professions. (II) Developments in OR techniques. (III) Military, industrial, government, and business application of OR.

The first theme is given special emphasis. Practitioners in many fields are encouraged to contribute papers that illustrate uses, or potential uses, of the OR approach in their specialty areas. This meeting should be valuable, as an introduction to OR methods, for persons in virtually all technical fields and professions.

The *Meeting Chairman* is DR. JOHN E. WALSH, *System Development Corporation, Santa Monica, California*. The deadline on submission of abstracts for contributed papers is 15 June 1964. Membership in an operations research society is not required for presentation of a contributed paper. In addition, a number of invited papers are being scheduled. The Keynote Address will be given by THE HONORABLE CHARLES J. HITCH, *Assistant Secretary of Defense, Comptroller*.

Persons interested in attending this meeting should contact the Meeting Chairman at once and obtain a questionnaire to be filled out concerning their desired travel arrangements. Prompt action in obtaining and returning this questionnaire is important in making suitable travel and hotel arrangements for the meeting.

THE REPORT OF THE 1962 LANCHESTER PRIZE COMMITTEE

M. L. ERNST, M. M. FLOOD, R. E. GOMORY

The 1962 Lanchester Prize Committee continued to follow the procedures developed by previous Committees. ORSA members selected for their knowledge of various fields of operations research were invited to select "... the best papers on operations research or reporting on an operations research study, identified as such". This year 50 publications were examined for prizeworthy papers by 93 screeners.

Coverage. All articles appearing in *Operations Research, Management Science,* the *Operational Research Quarterly,* and the *Naval Research Logistics Quarterly* were assigned individually, two screeners to a paper. All other publications were examined by two screeners each. The following publications were covered:

Administrative Science Quarterly
Advanced Management
Aeronautical Space Engineering
American Economic Review
Annals of Mathematical Statistics
Applied Statistics
Behavioral Science
Bell System Technical Journal
Biometrics
Biometrika
Canadian Journal of Mathematics
Conflict Resolution
Econometrica
The Engineering Economist
Ericsson Review
Harvard Business Review
Highway Research Board, NRC, Proceedings and Bulletins
Industrial Quality Control
Information and Control
Journal of the American Statistical Association
Journal of the Association for Computing Machinery
Journal of the Australian Mathematical Society
Journal of Farm Economics
Journal of the Franklin Institute
Journal of Industrial Engineering
Journal of the Operations Research Society of America
Journal of the Operations Research Society of Japan
Journal of the Royal Statistical Society (Series A and B)
Journal of the Society for Industrial and Applied Mathematics
Management and the Computer of the Future
Management Science
Management Technology
Naval Research Logistics Quarterly
Operational Research Quarterly
Proceedings of the AIEE
Proceedings of the AIIE
Proceedings of the Institute of Radio Engineers
Proceedings of the Joint Computer Conferences
Quarterly of Applied Mathematics
Quarterly Journal of Economics
Recent Developments in Information and Decision Processes
Review of Economics and Statistics
Review of Economic Studies
Self-Organizing Systems
SIAM Review
Sociometry
Technical Planning on the Corporate Level
Technometrics
Transactions of the ASQC
Transactions on Engineering Management

Screeners. Those who accepted service as screeners are listed below. This report carries with it the sincere thanks of the Committee and the Society for their efforts.

N. A. Ablahat
J. W. Abrams
J. H. Batchelor
S. Beer
E. O. Berdahl
B. Bernholtz
A. Blake
R. H. Blythe, Jr.
G. Brigham
F. C. Brooks
A. A. Brown
R. G. Brown
A. V. Butterworth
T. E. Caywood
G. K. Chacko
A. Charnes
L. S. Christie
C. W. Churchman
J. C. R. Clapham
I. H. Cole
R. R. Crane
W. E. Cushen
B. V. Dean
D. E. Debeau
W. L. Deemer
J. M. Dobbie
B. Dzielinski
L. C. Edie
J. H. Engel
W. R. Fair
G. J. Feeney
L. Friedman
D. P. Gaver
H. K. Gayer
D. C. Gazis
D. L. Gerlough
A. J. Goldman
S. K. Gupta
M. Halbert
F. J. Harris
J. H. Henry
D. B. Hertz
J. C. Hetrick
N. A. Hitchman
N. J. Hopkins
W. J. Horvath
D. Howland
E. M. Jacobs
W. S. Jewell
R. B. Johnson
A. W. Jones
J. E. Kelley, Jr.
E. Koenigsberg
R. L. Korgen
J. B. Lathrop
E. L. Leese
R. H. Lence
G. R. Lindsey
J. D. C. Little
B. O. Marshall, Jr.
J. F. McCloskey
A. M. Mood
G. E. Nicholson, Jr.
G. O'Brien
D. E. Oyster
G. S. Pettee
E. I. Pina
P. Ratoosh
P. J. Sandiford
M. W. Sasieni
M. G. Schorr
A. S. Schultz, Jr.
S. Sherman
J. Silber
N. M. Smith
J. Steinhardt
D. S. Stoller
R. J. Sutherland
W. H. Sutherland
(Miss) J. G. Taylor
C. J. Thomas
M. Trauring
G. W. Tyler
J. S. Vigder
H. M. Wagner
J. E. Walsh
R. S. Weinberg
H. K. Weiss
T. M. Whitin
W. F. Whitmore
R. I. Wilkinson
P. B. Wilson
S. Winkler

Selection of the Prize Paper. Twenty-nine articles from 13 publications were cited as prizeworthy by one or more screeners. All of these papers were then studied by the members of the Prize Committee. The Committee members also considered several additional papers from the literature which they thought worthy of participating in the final evaluation.

The Committee unanimously nominated the following paper for the prize: "Reducing Letter Delays in Post Offices," by R. M. Oliver and A. H. Samuel, published in OPERATIONS RESEARCH Vol. *10*, No. 6, Nov.–Dec. 1962, page 839.

The Committee regards the Oliver-Samuel paper as an excellent example of a case history, involving a combination of model development and data analysis. The problem treated is one which has an effect on the daily lives of all of us; the industry involved is a "classical" one, which has in the past received limited formal analytical study. The Committee considers that the authors developed the necessary model and mathematical background with considerable skill; although the models are basically simple, they are adequate for the purpose, and are substantiated by a series of experiments described in the paper. The end results are practical, and should make an effective contribution to improving the system under study. The Committee agreed with screeners' views concerning the clarity of exposition and the general excellence of the paper.

The Committee would like to express its great appreciation for the enormous amount of work done by Dr. James H. Griesmer of IBM Research in helping to organize and carry out the survey in a most efficient way.

PHILADELPHIA ORSA CHAPTER ACTIVITIES

The Philadelphia Chapter sponsored an all-day meeting on March 26, 1964 on "Operations Research in the Delaware Valley." The meeting, which was held at the Drexel Institute of Technology, featured a luncheon talk by DR. SIDNEY SHORE, Professor of Civil Engineering at the University of Pennsylvania, and DR. LEROY BROTHERS, Dean of Engineering at Drexel and past President of ORSA, on activities of the U. S. Air Force Operations Analysis Stand-by Unit at the University of Pennsylvania. Other speakers on the program were: DR. SIGURD L. ANDERSEN, E. I. DuPont de Nemours & Co., "A Push-Pull Marketing Model," MR LOUIS P. CLARK, Missile and Space Division, General Electric Co., "Arms Control and the Economy," MR. R. V. D. CAMPBELL, Burroughs Corp., "Operations Research in Defense R & D Planning," LT. CMDR. CHARLES W. RIXEY, U. S. Navy Field Assistance Group, "An Inventory Model for Reparables—Theory vs. Practice," DR. BRITTON HARRIS, University of Pennsylvania and the Penn-Jersey Transportation Study, "Decision-Oriented Models for Projecting Urban Growth Patterns."

ORSA WESTERN SECTION

Officers for 1964 are MARVIN LUTHER, *Chairman*; HARVEY WAGNER, *Vice-Chairman*; JOHN COLEMAN, *Secretary-Treasurer*. John Coleman's address is: *6450 Riggs Place, Los Angeles 45, California.*

UNIVERSITY OF CALIFORNIA STUDENT SECTION

At a special meeting held on November 5th, two changes were made to the Section's Constitution. *Article IV, Section 2*, was changed to: "The term of office shall be one year. Each officer will be elected at a special meeting during the Fall Semester. The elected officer . . ." *Article V, Section 1,* was changed to: "The regular meeting shall be held at least once each month during the school year. The time and place of each regular meeting shall be announced well in advance."

At the same meeting, new officers were elected. They are: *President:* RICHARD J. SWERSEY, *Vice-President:* ELLIS L. JOHNSON, *Secretary:* DANIEL P. HEYMAN, *Treasurer:* HERBERT R. PENNY and the address of the Section is:

Student Section of ORSA
Operations Research Center
1301 South 46th Street
Richmond, California

Speakers at this year's meetings have included WILLIAM JEWELL, BENNET FOX, HEINER MUELLER-MERBACH, RICHARD J. SWERSEY, and EDMUND EISENBERG.

REPORT OF THE EDUCATION COMMITTEE

The Education Committee has been concerned with formal programs of education in Operations Research. While many schools include a few Operations Research courses of study in both undergraduate and graduate curricula for the traditional disciplines, there are relatively few schools which have comprehensive programs in Operations Research itself. We believe that the future development of Operations Research depends in large measure upon the kind of education offered in Operations Research.

The Committee, therefore, intends to collect and publish information on the comprehensive programs for education in Operations Research available in educational institutions in the United States. The Committee will examine first those programs at institutions which offer both masters and doctoral degrees in the methods and applications of Operations Research. No attempt will be made by the Committee to define Operations Research for this purpose except to identify such programs and their curricular content more with Operations Research than with other traditional disciplines. The previous report (*OR Bulletin*, Vol. 11, Spring 1963, pp. B-76–99) contained the programs of *California* (Industrial Engineering, Berkeley), *Case, Cornell, Johns Hopkins, M.I.T.* and *Stanford.* Below are the programs of *California* (Business Administration, Berkeley), *Carnegie, New York University,* and *Northwestern.* Other programs will be published in the future.

ORSA Education Committee
HARVEY M. WAGNER, *Chairman*

UNIVERSITY OF CALIFORNIA (BERKELEY)

The curriculum in operations research leading to advanced degrees in this field was formally initiated in 1957 in the School of Business Administration. The objective is to prepare the student for advanced work in operations research either in its applications or in advanced basic research and in teaching. Emphasis is on the development of analytical abilities, on a thorough understanding of economics of organizational operations, on realistic problem formulation and solution, and on the significance of operations research as a social optimizing method.

I. Undergraduate Requirements

Students who enter the School of Business Administration with the equivalent of two full years of calculus and a course in statistics and probability theory may choose operations research as a field of emphasis. Such students are required to take Business Administration 193. These students also take two additional courses in mathematical programming, dynamic programming, queueing and inventory theory. They take special sections of the Core Curriculum in Business Administration in which quantitative models in marketing, production, finance and organization theory are discussed.

II. MBA and Ph.D. Requirements

A basic set of courses in economics and business administration is required of all MBA candidates. The core includes courses in micro-economic theory, accounting, production, finance, industrial relations, marketing and legal aspects of business administration. Students selecting the operations research option in the MBA program must have taken a two-semester course in calculus and one-semester course in statistics. They are recommended to take additional mathematical prerequisites amounting to four semesters of the calculus, a course in linear algebra and a course in probability theory as well as statistics.

For completion of the MBA program in operations research, students will normally select courses **B.A. 193, 293, 294, 295, 299** and an additional 3 courses selected from business administration, statistics and industrial engineering.

Ph.D. candidates must take qualifying examinations in Economic Theory and Organization Theory. In addition, they must take two qualifying examinations in fields approved by the Ph.D. Committee. These may include OR and Statistics. The student is then expected to prepare a thesis and may select a topic in the general area of OR and management science.

III. List of Operations Research Courses

B.A. 193. *Introduction to Operations Research*—Introduction to the history, practice, and nature of operations research; formulation of the problem; measuring costs; forecasting by probabilities. Models; sampling; recommendations; implementation and control; organization of operations research groups. "Introduction to Operations Research" by Churchman, Arnoff and Ackoff.

B.A. 210. *Seminar in application of digital computers to problems in the social sciences.* Problems and projects in the computer simulation of economic and industrial processes, thinking and learning processes, and neutral processes. Consideration of problems of artificial intelligence, mechanical linguistics and information retrieval.

B.A. 242. *Analysis of Production Management Problems.* Decision-making in production planning; types of decisions and variables involved; possibilities for quantification of variables; criteria for decision; methods of analysis. Emphasis is placed on applications of modern analytical methods in the solution of practical production problems.

B.A. 292. *Development of a Scientific Approach to Management.*

B.A. 293. *Seminar in Operations Research.* An advanced seminar. Discussion of the problems of mathematical models, measurement, organization of research and implementation. This seminar relates research and top-level organizational decision-making. The student will report on a topic of major interest selected by him. Ackoff's "Progress in Operations Research."

B.A. 294. *Measurement of Decision Criteria.* This seminar is essentially a study of models for measuring the values of objectives and a critical discussion of the problems involved. Churchman's "Prediction and Optimal Decision."

B.A. 295. *Inventory and Waiting Line Theory.* Analysis of inventory and scheduling problems, including formulation of management approaches to solutions, attention to the techniques of formal analysis and comparison of applications in various industries.

B.A. 299. *Research in Business Problems.* An operations research project conducted with a business firm or some other type of organization. The course 299 normally consists of the preparation of a paper based on an OR study for some business firm, government agency, university division or other organization. This study is begun in the fall semester and completed in the spring semester and may be done cooperatively with other MBA candidates.

Econ. 207A-207B. *Mathematical Economics.* Applications of mathematics to economic theory, including: utility and subjective probability, behavior of producers and consumers, equilibrium and optimum of an economy theories of games and organizations, economic growth, dynamic programming.

Econ. 203. *Mathematical Theories of Economic Planning.*

Additional courses in Industrial Engineering and Statistics. These include Industrial Engineering 161, 162, 163 and 264. Statistics 168, and 169. See previous announcements of operations research curriculum in Industrial Engineering, University of California, Berkeley, in the previous issue of the *ORSA Bulletin.*

IV. Research Activities

Center for Research in Management Science

The Center for Research in Management Science is an established center on the University of California Campus, Berkeley. Doctoral candidates are employed as research assistants to assist members of the faculty in their research on many of the grants. This provides both financial support for graduate students who are continuing a lengthy educational period, and research training and experience for them under recognized men in the field.

The Center's program also encourages visiting scholars to join the staff for work during the summer, or for other varying periods of time during the academic year.

Weekly seminars of the Faculty Council have a planned program followed by informal discussion. Such interchange of ideas and critical review of work in progress is an important stimulus to faculty research and interdisciplinary communication.

Current Projects

The special projects currently receiving outside support are indicative of the scope of the Center's research activities. The Carnegie Corporation of New York supports a program of research and education designed to contribute to the knowledge of human higher mental processes through the technique of computer simulation. The principal investigators are PROFESSORS EDWARD A. FEIGENBAUM and JULIAN FELDMAN. PROFESSOR FEIGENBAUM is concerned with a theory of the information processes by which the brain discriminates, memorizes and associates verbal symbols. PROFESSOR FELDMAN is concerned with building models of the information processes used by human beings to generate and test hypotheses about patterns in a series of two-choice events. These theories are realized in computer programs written in a computer language called IPL-V (short for Information-Processing Language, fifth version.)

The Office of Naval Research supports a project which consists of several related studies in the general area of economic analysis of problems of organization and information. From various points of view, these studies attack the problem of evaluation of information and decision systems, with particular attention to the costs, as well as the benefits, of such systems. PROFESSOR ROY RADNER, of the Department of Economics and Statistics is the principal investigator, working with PROFESSOR C. DEBREU, of the Department of Economics and THOMAS MARSCHAK, of the School of Business Administration. The project also provides an opportunity for four research assistants to further their work toward the Ph.D. degree. PROFESSOR BALDERSTON, through a grant from the Western Management Science Institute, has undertaken a program of research on two issues concerning multiple-branch organizations: evaluation of the performance of the manager of an individual branch of such an organization, in view of the objectives of the headquarters management group and, investigation of the patterns of interaction between headquarters, branches, and local clienteles in order to understand how such performance measures must operate in the actual context of such organizations.

Other studies by members of the Center indicate the range of research interests: CHURCHMAN, theories of value and of ethical appraisal; MARSCHAK, models of research and development administration; MATTESSICH, mathematical models of accounting; ANTON, accounting and other aspects of information systems in the business enterprise (including the recent construction, together with A. C. HOGGATT, of an elaborate computerized business game); RATOOSH, two-person non-zero sum games; BALDERSTON and HOGGATT, computer simulation of market processes; CHURCHMAN and RATOOSH, experiments on implementation of improved or optimal solutions in organizations; WHITIN, extensions of mathematical decision rules for inventory control; MARSCHAK and MCGUIRE, information technologies.

V. Faculty

Faculty primarily devoted to Operations Research

C. WEST CHURCHMAN, Ph.D., *Professor of Business Administration and Research Economist*

FREDERICK E. BALDERSTON, Ph.D., *Professor and Chairman, Center for Research in Management Science*

A. C. HOGGATT, Ph.D., *Associate Professor of Business Administration*

C. B. MCGUIRE, *Associate Professor of Business Administration*

JACK ROGERS, Ph.D., *Associate Professor of Business Administration*
E. A. FEIGENBAUM, Ph.D., *Assistant Professor of Business Administration*
JULIAN FELDMAN, Ph.D., *Assistant Professor of Business Administration*
TOM MARSCHAK, Ph.D., *Assistant Professor of Business Administration*

Associated Faculty in Other Departments of Instruction

RONALD W. SHEPHARD, Ph.D., *Professor Chairman of the Department of Industrial Engineering*
GEORGE B. DANTZIG, Ph.D., *Professor and Chairman of the Operations Research Center*
ROBERT OLIVER, Ph.D., *Associate Professor and Associate Research Engineer, Institute of Transportation and Traffic Engineering.*
WILLIAM S. JEWELL, Ph.D., *Assistant Professor*
EDMUND EISENBERG, Ph.D., *Assistant Professor*
Assistant Research Engineer, Operations Research Center
ERNEST KOENIGSBERG, Ph.D., *Lecturer,*
Director of Operations Research, CEIR (San Francisco)
DAVID BLACKWELL, Ph.D., *Professor of Statistics*
EDWARD W. BARANKIN, Ph.D., *Professor of Statistics*
ROY RADNER, Ph.D., *Professor of Economics and Statistics*
DALE W. JORGENSON, Ph.D., *Associate Professor of Economics*

VI. Ph.D. Graduates

RUSSELL TAUSSIG
Doctor of Philosophy—Jan. 1962
Dissertation: Operational Accounting for Replacement Models
DONALD ABE
Doctor of Philosophy—June 1963
Dissertation: Data for Managerial Control
ROBERT BARTON
Doctor of Philosophy—September 1961
Dissertation: Business Decision Theory

CARNEGIE INSTITUTE OF TECHNOLOGY

I. Introduction

Operations Research at the Graduate School of Industrial Administration integrates knowledge of management problems with competence in developing and applying techniques for their solution. An experimental and innovative approach to teaching and research encompasses work in the underlying disciplines of applied mathematics and statistics, organizational theory and social psychology, and mathematical and managerial economics. Fundamental efforts in these areas are directed toward the conception of quantitative methods, understanding of basic managerial and organizational processes, and design of research tools which contribute to the evolution of a more adequate science and discipline of management. Complementary effort is devoted to more systematic structuring of management processes in such areas as production, labor relations, marketing, and business planning. The Graduate School of Industrial Administration has tried to avoid drawing narrow and, of necessity, arbitrary boundary lines around the rapidly changing and relatively new applied science of operations research. The School bases its programs on the premise that interdisciplinary approaches to research and close connections between technique oriented and problem oriented interests best can provide significant contributions to basic knowledge and to the analysis and design of improved management systems.

In addition to teaching and research in management science within the Graduate School of Industrial Administration, closely related efforts are in progress in the Departments of Mathematics, Electrical Engineering, and Psychology, and in the interdisciplinary Systems and Communication Sciences program. Relevant degree programs at the graduate level include the M.S. program in Industrial Administration in which students may elect a concentration in operations research, the Ph.D. in Economics with emphasis on applications of OR methods to the analysis of macro and micro economic systems, the Ph.D. in Industrial Administration with majors in either management science or systems and communication science, and a new joint doctoral program between GSIA and the Department of Mathematics in Mathematical Economics and Management Science.

II. Full Time Faculty Primarily Associated with OR Programs

Name	*School or Department*	*Teaching and Research Activities*
J. Bossens	GSIA	application of quantitative methods to problems of financial analysis
K. J. Cohen	GSIA	operations research, quantitative analysis of economic systems, simulation of managerial and economic systems
W. W. Cooper	GSIA	operations research, planning and control of industrial systems, mathematical programming
O. A. Davis	GSIA	statistics and mathematical programming
M. H. DeGroot	GSIA/Mathematics	statistics and applied mathematics
M. Hinich	GSIA	statistics
J. F. Muth	GSIA	production planning and control, mathematical economics
A. Newell	Institute Professor of S and CS	systems design, simulation of human thinking and problem solving processes, computer programming languages
H. A. Simon	GSIA/Psychology	systems design, simulation of complex information processes, operations research, mathematical techniques for social sciences

Name	*School or Department*	*Teaching and Research Activities*
F. M. Tonge	GSIA	quantitative methods for production planning and control, electronic data processing systems computer simulation techniques
G. L. Thompson	GSIA/Mathematics	finite mathematics, applications to management planning operation, control problems

III. Full Time Faculty in Areas Related to Operations Research Programs

Name	*School or Department*	*Teaching and Research Interests*
H. I. Ansoff	GSIA	business planning, management decision making and control problems
R. G. Brandenburg	GSIA	production, R and D planning, management decision making and control problems
N. C. Churchill	GSIA	techniques and systems for managerial control
R. M. Cyert	GSIA	statistical applications to managerial and economic problems, business decision making and organization behavior
W. R. Dill	GSIA	business planning, management simulation exercises
R. J. Duffin	Mathematics	development of new mathematical techniques, investigation of mathematical implications of O.R. methods
B. F. Green, Jr.	Psychology	complex information processes, psychometrics
L. W. Gregg	Psychology	human engineering, complex information processing systems
A. A. Kuehn	GSIA	analytical techniques for analysis and solution of marketing problems
K. R. MacCrimmon	GSIA	production planning, organization theory
J. G. March	GSIA	organization theory, organization design
A. J. Perlis	Mathematics	computer programming, systems analysis and design
W. R. Reitman	GSIA/Psychology	cognitive processes, computer simulation of problem solving

IV. Ph.D. Degrees Awarded Primarily in Operations Research

Name	*Year*	*Thesis Title*
A. NEWELL	1957	Information Processing: A New Technique for the Behavioral Sciences
A. A. KUEHN	1958	An Analysis of the Dynamics of Consumer Behavior and Its Implications for Marketing Management
P. R. WINTERS	1958	Inventory Control in a Multiple Warehouse System
A. K. ANDO	1959	A Contribution to the Theory of Economic Fluctuations and Growth
K. J. COHEN	1959	Computer Models of the Shoe, Leather, Hide Sequence
A. C. STEDRY	1959	Budget Control and Cost Behavior
F. M. TONGE, JR.	1960	A Heuristic Program for Assembly Line Balancing
G. P. E. CLARKSON	1961	The Meno Anew: A Simulation of Trust Investment
C. BONINI	1962	Accounting Information Systems in the Firm
J. F. MUTH	1962	Optimal Linear Policies
H. M. WEINGARTNER	1962	Mathematical Programming and the Analysis of Capital Budgets
A. B. WHINSTON	1962	Price Coordination in Decentralized Systems
W. S. GERE, JR.	1963	A Heuristic Approach to Job Shop Scheduling
Y. IJIRI	1963	Goal Oriented Models for Accounting and Control
T. A. VAN WORMER	1963	The Trimmer—A Heuristic Approach to the Trim Problem in the Corregated Container Industry
J. D. WIEST	1963	Computer Models for the Scheduling of Large Projects
O. E. WILLIAMSON	1963	The Economics of Discretionary Behavior: Nonpecuniary Objectives in the Theory of the Firm

V. Courses Primarily in Operations Research and Related Subjects

Quantitative Controls in Business I and II (two semesters). A sequence aimed at developing understanding of and ability to use the basic quantitative techniques (accounting, statistics, budgeting) of business and economics. The sequence is taught with reference to a series of problems developing the role of quantitative data and techniques in management planning and control, production, financial and cost control, market analysis, and general administration.

Mathematical Foundations of Management Science I and II (two semesters). A course to provide the mathematical foundations, beyond the calculus, for students especially interested in management science, operations analysis, and research in the social sciences. Differential and difference equations, linear algebra, and stochastic processes are emphasized. First semester may be taken alone.

The Management Game. A simulation of a competitive industry in which students assume responsibility for major managerial functions of different firms. The purpose is to provide guided experience in managerial decision-making under conditions of competition and uncertainty.

Mathematical Social Science. The applications of mathematical tools, including differential equations and modern algebra, to the analysis of sociological, organizational and political phenomena. Methods and problems of model construction, and testing of hypotheses Applications of laboratory and field studies of small groups, organizational behavior, and social behavior.

Complex Information Processing Systems. A seminar on the theory of complex information processes and techniques for studying information processing systems, including their realization by electronic computers. Applications to human problem-solving and other cognitive processes and to business decision-making problems.

Business Controls and Information Systems. Analysis of control and coordination problems in micro and macro units of a business. Information and organization devices are assessed by means of business case studies, managerial-psychological experiments and analytic formulations.

Production II. An advanced seminar in the application of modern management science and operations research techniques to problems in the production area, with emphasis on production planning, inventory control, and related areas.

Production III. An advanced seminar in manufacturing operations and policy, centering around selected problems of interest from year to year.

Marketing II. A seminar in marketing policies and research. Special emphasis is placed on analysis of consumer behavior, studies of market potentials, and determination of marketing price and advertising strategies. Considerable use is made of modern management science tools where they are appropriate.

Finance III. A research-oriented course with emphasis on the analysis of financial problems as they arise in non-financial and financial firms. Review of current research publications and development of quantitative techniques for the solution of financial problems. Individual and group research projects are stressed.

Advanced Statistics (two semesters). Statistical description and statistical inference, probability, frequency distributions, small and large sample theory, hypothesis testing and estimation. Sampling-simple, stratified and multi-stage; bivariate and multivariate analysis, including correlation, regression, and analysis of variance.

Operations Research I. A survey of Operations Research in a variety of managerial areas, emphasizing problem formulation. The topics include: introduction to the use of electronic computers and computer programming, waiting line analysis, linear programming, games of strategy, statistical decisions, and computer simulation of business procedures.

Operations Research II. A course which emphasizes the management of formalized studies of planning, decision-making, and control processes in business. Selected operations research applications will be considered in depth, including large scale programming problems, stochastic systems, and mixed competitive-cooperative systems. Attention is given to problems of administering, implementing, and validating operations research studies.

Operations Research Seminar. Extensions and applications of operations research techniques to managerial problems. Students will formulate and conduct actual operations research projects.

Seminar in Systems and Communication Sciences. A seminar, primarily for students in the Systems and Communication Sciences program, in the handling of simple and complex problems involving a systems approach. Problems involve organizational, engineering, mathematical, and combined man-machine systems. The complexity of problems increases each semester. Students work partially on problems of their own choosing.

Behavioral Theory of the Firm. An examination of economic and behavioral theories of the firm; decision-making activities of business organizations in competitive, oligopolistic, monopolistic markets; formulation of organizational objectives, processing of information, use of budgets and other control techniques, and influence structure of the organization as they affect major organizational decisions.

Econometrics. A research seminar stressing statistical methods of econometrics and their application for explanation and prediction in macro and micro economics systems.

Electronic Data Processing. The role of information flows in business organizations and their relation to integrated data processing systems. Electronic digital computers and other devices for storing, processing, and transmitting information. Feasibility analyses for determining the economic desirability of electronic data processing systems, and problems involved in their installation.

Principles of Programming for Digital Computers (two semesters). Advanced programming techniques, such as interpretative, assembly, and compiler routines and their applications. Micro-programming. Applications of digital computers to problems of real time simulation, continuous process simulation, engineering design, scientific calculations, file design and maintenance, and general information processing. Influence of programming on computer design. First semester may be taken alone.

In addition to the courses listed above, a variety of additional graduate level courses and seminars are offered in the related areas of administrative behavior, organization behavior, economics of the firm, consumer behavior and marketing strategy, macro economics, welfare economics, and economic analysis and policy. Related courses offered in other academic divisions include human engineering, industrial and social psychology, research methods in the behavioral sciences, probability theory, modern algebra, numerical analysis, measure theory, information theory, and feedback control systems.

VI. Research Dealing Specifically with Problems of Operations Research

Relevant ongoing research activities in the Graduate School of Industrial Administration include investigations of problems of management control and coordination, strategic management decision making, planning under conditions of certainty, planning under risk and uncertainty, critical path scheduling, applications of heuristic programming techniques to production and marketing problems, developments in mathematical programming, and the design and utilization of complex simulations as learning environments. Other investigations are in progress in the areas of complex information processing, aimed at obtaining a fuller understanding of problem solving, learning and decision making. A variety of projects are devoted to the study of the actual process of decision making in complex organizations, in which the inferences derived from computers are being related to models of classical economics and political science. In other areas, computer simulations are being designed and tested for investigating price, advertising, and product behavior in the cigarette industry; commercial bank behavior, and consumer brand shifting and product preference behavior.

VII. Requirements for M.S. and Ph.D.

A. *Prerequisites:*	*M.S.*	*Ph.D.*
Undergraduate degree in engineering, science, or mathematics (if another background, must know mathematics through calculus). Good score on ATGSB or GRE Aptitude test:	General minimum on ATGSB 45–50th percentile, class mean, 80–85 percentile	General minimum on ATGSB 80–85th percentile, class mean, 95th percentile
Overall record and recommendations that indicate:	Ability to maintain minimum of 3.00 average on 4.00 scale in graduate school and ability to be a leader in management.	Ability to maintain an average better than 3.00 on a 4.00 scale in graduate school and ability to do outstanding work in research and teaching.

B. *Requirements for M.S. degree:*

Requirements for M.S. degree with an O.R. option: To complete an approved program of courses requiring two years of full time study with at least a 3.00 average (on a 4.00 scale) and to pass an M.S. comprehensive examination at the end of the second year. The normal program includes courses in:

The foundation disciplines: Administration and behavioral sciences, economics and the environment of business, and quantitative methods (including operations research techniques).

The functional fields of management: Marketing, production, finance, and labor.

General managerial problem-solving: Assignments crossing over course boundaries, including a semester's experience in a complex management game and a business policy case and problems course.

Advanced electives: From offerings within the School and from offerings of other departments on campus.

C. Requirements for Ph.D. degree:

Requirements for the Ph.D. in Industrial Administration are tailored to the interests of each man. Students electing to major in management science take programs emphasizing the development and use of modern theoretical, quantitative, and mathematical tools for the analysis of phenomena directly related to the functional fields of industrial administration (e.g., marketing, finance, production, industrial relations, managerial control). Research is directed toward inventing, elaborating, and applying new techniques of operations research and toward understanding and improving management practice. With a Systems and Communication Sciences major, emphasis is on the communication and transformation of information in complex systems—particularly as reflected in the areas of computer programming, simulation of human cognitive processes, artificial intelligence, adaptive control of continuous processes, and in the management sciences.

The Doctoral Program in Economics, with emphasis on mathematical and managerial economics, encompasses training aimed toward an "econometrics" approach to the analysis of the behavior of individuals, firms and the economy as a whole and management science and operations research applications of economic analysis in business and industry. The program involves utilization of the tools of mathematics and quantitative methods. Students may emphasize the applications of economic analysis to industrial and other managerial problems, may stress applications of economic theory and quantitative methods to economy-wide problems, or may specialize in the tools of economic theory and quantitative methods themselves.

The Ph.D. program in mathematical economics and management science is designed for students desiring to concentrate more intensively on mathematical techniques. Students electing this program must pass a major examination in the Department of Mathematics, and three minor examinations in the Graduate School of Industrial Administration.

Students are encouraged to supplement participation in courses and seminars with programs of independent study and research. Students must show proficiency in this work and must pass a set of four preliminary examinations to be admitted to candidacy for the degree. Students are also required to pass competency examinations in mathematics and one foreign language and to write a dissertation which shows competence for independent and original research.

The Ph.D. program normally takes a minimum of at least three years of full-time study to complete.

NEW YORK UNIVERSITY

I. *Administrative Relationships*

Until 1961, Operations Research was a field of specialization in the Department of Industrial Engineering at New York University. In 1961, a separate degree program in operations research was established, with B.S., M.S., and Ph.D. degrees and the name of the department was changed to the Department of Industrial Engineering and Operations Research.

It is felt that graduate study is an essential prerequisite for high level work in operations research and that the student wishing to enter this field should normally prepare to continue his studies beyond the bachelor level. Accordingly, his undergraduate training places heavy emphasis on mathematics and the basic psychological and social sciences which are necessary for graduate study in this field. Since the undergraduate operations research curriculum is primarily intended to prepare the student for graduate work, all operations research undergraduates have their records evaluated at the end of the sophomore year and only those who have shown a firm grasp of the basic scientific disciplines important to operations research are allowed to continue in the curriculum.

II. *Graduate Program in Operations Research*

The objective of graduate study in operations research is to advance the understanding, prediction, and control of integrated systems of men and equipment. This involves the mathematical and scientific methods by which principles may be formulated, tested, and confirmed, as well as human, technological and economic factors.

The operations researcher should be skilled in the design and execution of research and in the mathematical and statistical tools needed for analyzing data and making predictive models. He should also be conversant with the problems and techniques of management. Since the field is so broad, students will usually concentrate on one or several aspects, depending on their interests and abilities. For example, some may emphasize the statistical and mathematical facets, other the economic, and still others the psychological. All should be familiar with the common quantitative and scientific framework and have at least basic competence in the several specialties.

This program, leading to the degrees of Master of Science (in Operations Research) and Doctor of Philosophy, is open to qualified students with undergraduate degrees in engineering, mathematics, physical science, or quantitative behavioral or economic science.

Students who have not had basic courses, undergraduate or graduate, in areas fundamental to the field (modern algebra, probability and statistics, advanced calculus, economic analysis, industrial behavior), are expected to take these courses. Students who have an extensive background in one or more of the listed areas will be excused from taking these basic courses upon passing an examination.

In recognition of the wide scope of operations research, the department has included relevant subjects from many disciplines among its offerings and has also made arrangements whereby its students may do specialized work in the Graduate School of Arts and Science, including the Courant Institute of Mathematical Sciences. Courses in this department are categorized in four groups: (A) quantitative foundations, (B) engineering, (C) social science foundations, and (D) management. M.S. students must select at least 12 credits from Group A.

The doctoral student will normally select a minor in a relevant scientific discipline such as statistics, mathematics, physics, chemistry, psychology, and economics. (The scientific basis of operations research has not yet developed an independent body of scientific knowledge in sufficient depth to provide status as a separate science. There is thus an educational need for competence in depth in some other science to provide necessary methodological discipline.)

The sum total of course work, practical experience, research, and other studies during the period of work toward the doctorate should be so patterned as to enable the student to gain mastery of the entire field. Research in operations research depends upon the student's appreciation of the relevant variables and their interrelations. This appreciation frequently cannot be gained solely through course work. When this is true, it is expected that doctoral students will acquire appropriate firsthand scientific experience prior to initiation of thesis research. This experience may be acquired on either a full-time or part-time basis, prior to or concurrent with graduate study, in educational, industrial, or governmental employment. The experience may be in professional practice or scientific research, depending on the student's proposed thesis topic.

Before starting his thesis research, the doctoral student must satisfy an examining committee that he is competent in both his major and minor fields. The committee will test the student's ability to use and integrate the different methods and techniques of operations research; to conduct independent research in his major field; and his competence in his minor (scientific) field.

The principal purpose of the student's thesis research is to develop and demonstrate the independent research competence of the candidate. It should represent a significant contribution to the theory, practice, or research methods of Industrial Engineering or Operations Research. It will normally consist of:

1. The development and solution of a mathematical model to describe or predict some event, often followed by a test of the validity of the model.
2. A controlled experiment, which may involve simulation, in which an experimental sample is manipulated and compared with similar groups which are not so manipulated or are manipulated differently. This is also sometimes followed by a test of the validity of the conclusions.
3. A natural experiment, in which differences analogous to the controlled experiment exist in the population, and in which observations are then analyzed statistically.

III. Graduate Courses (Partial Listing)

Following is a partial listing of graduate courses offered in the Department of Industrial Engineering and Operations Research:

T58.1110	*Individual Behavior in Industry*
T58.1150	*Industrial Safety Engineering*
T58.1182	*Engineering Economics*
T58.1186	*Computer Methodology*
T58.1187	*Deterministic Methods*
T58.1188	*Engineering Statistics I*
T58.1189	*Engineering Statistics II*
T58.2206	*Production Planning and Control*
T58.2210	*Industrial Economics*
T58.2211	*Social Factors in Industrial Behavior*
T58.2215	*Systems Analysis and Design*
T58.2216	*Theory of Organization*
T58.2229	*Human Factors in Engineering Design*
T58.2233	*Statistical Quality Control*
T58.2234	*Advanced Quality Control*
T58.2236	*Computer Applications*
T58.2237	*Linear Programming*
T58.2238	*Introduction to Operations Research*
T58.2246	*Systems Simulation*
T58.2247	*Nonlinear and Dynamic Programming*
T58.2250	*Applications of Probability*
T58.2251	*Queuing and Related Stochastic Processes*
T58.2252	*Industrial Experimentation I*
T58.2253	*Industrial Experimentation II*
T58.2254	*Reliability and Life Testing*
T58.2258	*Applications of Nonparametric Statistics*
T58.2266	*Special Topics in Industrial Engineering and Operations Research*
T58.2290	*Research Frontiers*
T58.2292	*Advanced Seminar in Industrial Economics*
T58.2296	*Advanced Topics in Organizational Behavior*
T58.3300	*Research for the Master's Degree*
T58.3301	*Research for the Doctorate*

Following are a few of the graduate courses offered by other departments of the University which are relevant to our Operations Research program:

Department of Electrical Engineering:

T34.1303	*Analogue Computers*
T34.1304	*Introduction to Digital Computer Engineering*
T34.2603–4	*Information, Prediction, and Filtering Theory*
T34.2606	*Systems Engineering*
T34.2607–8	*Statistical Communication Theory I, II*

Department of Mathematics:

G63.1050–60	*Introduction to Numerical Methods*
G63.2030–40	*Advanced Numerical Methods*
G63.2050–60	*Special Topics in Numerical Methods*
G63.2070–80	*Logic of Computation*

Department of Economics:

G31.2101–2	*Mathematical Economics*
G31.2105–6	*Econometrics*
G31.2113	*Time Series and Forecasting*
G31.3007–8	*Theory of Economic Growth*

Department of Psychology

G89.2243–4	*Psychometric Theory*
G89.2217	*Social Psychology*
G89.2241–2	*Industrial Psychology*
G89.2248	*Laboratory in Experimentation on Social Interaction*
G89.2252	*Laboratory in Personnel Research*

IV. Basic and Applied Research

The staff of the Department of Industrial Engineering and Operations Research engages in research covering a broad spectrum of operations research activities. Investigations are currently being carried out under the sponsorship of many organizations, including the Air Force Office of Scientific Research, the Office of Naval Research, the Army Research Office (Durham), the Army Chemical Research and Development Laboratories, the National Institutes of Health, and the Ford Foundation. These investigations cover such topics as: methods of improving the efficiency and effectiveness of statistical simulation procedures; differences in the safety characteristics of roadways, utilizing the methods of stochastic processes; establishment of a mathematical model for the effectiveness of a chemical agent; determining the effectiveness of executive development programs; a study of job rating and performance; criterional variables and their use in identifying the operation of independent variables; randomization procedures and factorial experimentation; and factors affecting information storage and retrieval in man.

Research assistantships are available to qualified students.

V. Full Time Faculty Members in the Department of Industrial Engineering and Operations Research

NORMAN N. BARISH, *Professor and Chairman.* B.S. (Econ.) 1940, C.C.N.Y.; B.S.E.(M.E.) 1943, Michigan; M.S.(M.E.) 1945, Pennsylvania. Economics; management and organization analysis; information and control systems.

RAYMOND A. KATZELL, *Professor.* B.S. 1939, A M. 1941, Ph.D. 1943, New York University. Industrial psychology; organizational theory.

JOSEPH WEITZ, *Professor.* B.S. 1937, Carnegie Institute of Technology; M A. 1938, Ph.D. 1940, University of Virginia. Industrial psychology.

HAROLD K. WORK, *Professor.* A.B. 1923, Ch.E. 1925, Columbia; Ph.D. 1929, Pittsburgh. Research Management.

RICHARD S. BARRETT, *Associate Professor.* B.S. 1948, Cornell; A.M. 1951, Syracuse; Ph.D. 1956, Western Reserve. Perceptions of job requirements and performance; performance measurement; selection.

LEON H. HERBACH, *Associate Professor.* A.B. 1943, Brooklyn College; A.M. 1947, Ph.D. 1957, Columbia. Engineering statistics; life testing; reliability and mathematical models.

JOHN H. K. KAO, *Associate Professor*. B.S. 1939, National Central University; M.S. 1953, D.Eng.Sc. 1962, Columbia. Reliability engineering (computers and systems); quality control and sampling inspection.

MARK S. MAYZNER, *Associate Professor*. B.A. 1952, A.M. 1954, Ph.D. 1955, New York University. Engineering psychology; human factors.

KARL A. HAAS, *Assistant Professor*. B.Mgt.Eng. 1959, M.Mgt.Eng. 1960, Rensselaer Polytechnic Institute. Methods and standards engineering; production planning and control.

NORBERT HAUSER, *Assistant Professor*. B.M.E. 1950, Cooper Union; M.Ind.E 1955, D.Eng.Sc. 1962, New York University. Quality control; economic analysis; systems simulation; computer methodology and applications.

EUGENE D. HOMER, *Assistant Professor*. B.Ind.E. 1954, M.Ind.E. 1958, New York University. Data processing; management information and control, systems; inventory and production theory.

LLOYD ROSENBERG, *Assistant Professor*. B.A. 1955, Brooklyn College; M.S. 1957, Iowa State University; Ph.D. 1962, Columbia. Queuing and stochastic processes; linear programming.

SAMUEL S. STEPHENSON, JR., *Assistant Professor*. B.E.E. 1945, Manhattan; M.Ind.E. 1948, Stevens; D.Eng.Sc. 1962, New York University. Cost control; industrial management; methods engineering.

HAROLD GREENBERG, *Lecturer*. B.A. 1949, Brooklyn College; M.S. 1958, New York University. Operations research; traffic flow; reliability, mathematical models.

SEYMOUR KAPLAN, *Lecturer*. B.S. 1950, Newark College of Engineering; M.S. 1952, New York University. Operations analysis and mathematical models.

IRWIN GREENBERG, *Instructor*. B.I.E. 1956, New York University; M.S. 1960, Northeastern. Probability, operations analysis, traffic flow.'

VI. Associated Faculty in Areas Related to Operations Research Program

Mathematics and Statistics:

FREDERICK A. FICKEN, A.B., A.M., A.B.(Oxon), Ph.D., *Professor*.
MARCK FISZ, Mag.Fil., Sc.D., *Professor*.
JACK HELLER, B.Aero.E., M.Aero.E., Ph.D., *Professor*.
WARREN M. HIRSCH, A.B., M.S., Ph.D., *Associate Professor*.
KENNETH S. MILLER, B S.(Chem.Eng.), A.M., Ph.D., *Professor*.
MAX A. WOODBURY, B.S., M.S., Ph.D., *Professor*.

Economics:

SOLOMON FABRICANT, B.S., B.C.S., A.M., Ph.D., *Professor*.
BENJAMIN J. KATZ, A.B., A.M., Ph.D., *Associate Professor*.
BRUNO STEIN, A.B., A.M., Ph.D., *Assistant Professor*.

Psychology:

ARTHUR R. COHEN, A.B., A.M., Ph.D., *Associate Professor*.
JACOB COHEN, B.S., A.M., Ph.D., *Associate Professor*.
LAWRENCE KARLIN, A.B., A.M., Ph.D., *Associate Professor*.

Electrical Engineering:

SHELDON S. CHANG, B.S., M.S., Ph.D., *Professor.*
ANDREW R. COHEN, B.S., M.S., Ph.D., *Assistant Professor.*
HERBERT FREEMAN, B.S., M.S., Eng.Sc.D., *Associate Professor.*
LUDWIK KURZ, B.E.E., M.E.E., Eng.Sc.D., *Assistant Professor.*
JOHN R. RAGAZZINI, B.S., A.M., Ph.D., E.E., *Professor.*

Civil Engineering:

WILLIAM E. DOBBINS, B.S.(Sanitary Eng.), M.S.(Sanitary Eng.), Ph.D., *Professor.*

Meteorology:

BEN DAVIDSON, A.B., M.S., Ph.D., *Associate Professor.*

VII. Recent Doctoral Graduates

Name	*Thesis*
SIDNEY A. WHITT—June 1962	Relation of high effective temperature to physiological demand in light physical work.
NORBERT HAUSER—June 1962	Economic design of control charts for process adjustment.
SAMUEL S. STEPHENSON, Jr.—October 1962	A method of measuring the productivity of an industrial enterprise.

Doctoral theses nearing completion are on such topics as: transient solutions for (s,S) inventory problems; parameter estimation in a simple queue; methods of minimizing length of run in queuing simulations; a heuristic program for a production system exhibiting non-Markovian characteristics; the effect of organizational structure on performance of engineering-design groups.

VIII. Applications for Admission and Fellowships

Persons who are interested in undertaking a program leading to the Master's degree or to the Doctor of Philosophy in Operations Research should write to PROFESSOR NORMAN N. BARISH, *Chairman, Department of Industrial Engineering and Operations Research.* Further information about these programs appear in *The Announcement of the Graduate Division, School of Engineering and Science.* Fellowships, assistantships, and scholarships are available.

NORTHWESTERN UNIVERSITY

I. Faculty

Full time faculty members who associate themselves primarily with Operations Research together with the subjects they teach and their research specialties.

DR. A. CHARNES, *Professor of Engineering Sciences and Professor of Mathematics and Economics*
DR. L. G. MITTEN, *Professor of Industrial Engineering and Management Sciences*

Dr. A. H. Rubenstein, *Professor of Industrial Engineering and Management Sciences*

Dr. G. K. Krulee, *Associate Professor of Industrial Engineering and Management Sciences*

Dr. G. J. Rath, *Associate Professor of Industrial Engineering and Management Sciences*

Mr. B. McK. Johnson, *Assistant Professor of Industrial Engineering and Management Sciences*

Dr. S. Singer, *Assistant Professor of Industrial Engineering and Management Sciences*

Dr. A. P. Hurter, *Assistant Professor of Industrial Engineering and Management Sciences and Assistant Professor of Transportation Center*

Other faculty members supporting the Operations Research Program.

Meyer Dwass, *Professor of Mathematics*

Leon N. Moses, *Director of Research Division and Professor of Transportation Center*

Jerome Sacks, *Associate Professor of Mathematics*

Paul W. Shuldiner, *Assistant Professor Civil Engineering*

Ivar Stakgold, *Associate Professor Engineering Sciences*

Robert H. Strotz, *Professor of Economics*

II. Graduates

Ph.D. Graduates who have been educated primarily as Operations Research Practitioners along with Ph.D. Theses subjects and all degrees held by Operations Research Graduates.

1960—Ph.D.

Shetty, C. M., "Analytical Methods of Process Analyses Including Techniques for Sensitivity and Quadratic Programming."

1961—Ph.D.

Beightler, Charles S., "Systems of Interrelated Quality Control Stations Structured as Multi-Stage Decision Processes."

1961—Ph.D.

Garver, L. L., "Economic Scheduling of Electric Power Generators by Integer Programming."

1961—Ph.D.

Nemhauser, George L., "A Dynamic Approach for Optimal Design and Operation of Multi-Stage Systems in the Process Industries."

1962—Ph.D.

Lynn, W., "Design Extension and Financing of Municipal Sanitary Facilities."

III. Research Studies Currently Being Carried Out by Graduate Students Who Are Primarily Employed in Operations Research

Scheduling of closed loop transportation systems with dynamic demands.

General Duality theorems and mathematical programming, mathematical models of organizations, statistical methods of organization sampling.

Study of the combined inventory production scheduling problem.

Computational methods in non-linear programming and chance constrained models.

Control theoretic models of multi-level production inventory systems.

Systems studies in water pollution.

Stochastic Processes.

Studies in optimal extension maintenance and financing of highways.

Studies in non-linear production smoothing.

Chance constrained models in econometrics.

Mathematical models in research and development with respect to project selection.

Investigating the use of simulation techniques for analyzing a combinatorial problem in machine placement, in which the measure of effectiveness being optimized is an arbitrary function.

Design, extension, and financing of municipal sanitary facilities.

Study of two class, single channel queues.

Studies of production control with variable demand.

IV. Courses Offered

Catalogue descriptions (including text books used) of all courses of study which are classed primarily as Operations Research:

Department of Engineering Sciences:

D87—*Competitive Systems Analysis:* Theories and models for the study and evaluation of economic engineering and managerial systems in its competitive aspects. Mimeographed literature and text book: *Management Models and Industrial Applications of Linear Programming,* Volumes I and II.

D88—*Extermal Methods and Systems Analysis:* The theory and applications of extremal techniques to problems of management engineering design, organizational control, and stochastic design theory. Text book: *Management Models and Industrial Applications of Linear Programming,* Vol. I and II, Charnes and Cooper.

Department of Industrial Engineering and Management Sciences:

C11, C12—*Quantitative Methods In Industrial Engineering I, II:* Applications of symbolic logic, set theory, matrix algebra, fields, vector spaces, linear transformations, convex sets, constrained extremum theory, the calculus of finite differences, operator and and transform methods, and the theory of stochastic processes.

C31, C32, C33—*Industrial Engineering Design I, II, III:* A series dealing with the design of work systems that integrate man, materials and equipment, using the basic concepts and procedures of systems design. The first course draws upon Operations Research tools as related to systems design; the second centers around the "production" system, automation, and control; the third is an integration of all work into an over-all large-scale systems design, including information and data processing, and the human factor.

C40—*Introduction To Organization Theory:* The course consists of two parts: (1) Examination of the basis for useful theories of organizational behavior and requirements for successful design and control of industrial organizations and their components. (2) Case studies of programs carried on and methods used by Industrial Engineering, operations research, and management science groups in industrial and other organizations.

C53—*Operations Research:* The application of operations research techniques to industrial problems. Study of methods of operations research, including conceptual models, measures of effectiveness, sampling techniques, statistical methods, and probability models with specific applications in business and industry. Case study exercises on problems of production and inventory control, queuing, programming, replacement, game theory, and information theory.

D10—*Organization Theory:* Examination of the basis for useful theories of organizational behavior. Requirements for successful design and control of industrial organizations and their components. Study of selected problem areas: decision-making, communication, measurement of organizational effectiveness, etc.

D20—*Introduction To Operations Research:* A study of research methods useful for solving complex operational problems by use of classical scientific and engineering tools combined with advanced mathematical techniques. Concepts and philosophies are reviewed, techniques are surveyed, and case applications are studied.

D21, D22, D23—*Operations Research I, II, III:* A continuation of D20, concentrating on specific problem areas associated with Industrial Engineering.

D40-1, 2, 3—*Information And Data Processing I, II, III:* The study of the information requirements of large-scale systems. Probability theory and information theory, components and operation of analog and digital computers, digital-analog and analog-digital converters, and the analysis of large-scale data processing systems incorporating digital computers.

D50—*Analysis And Design Of Control Systems:* Examples of large-scale systems, use of mathematical models, data-gathering, and the use of statistics in defining the design problems. System logic, queuing theory, game theory, linear programming, simulation, and human engineering applied in the design of large-scale work systems.

E11, E20, E30—Seminar taking up advanced problems of interest to faculty and students. No text.

E80—*Research For Master's Thesis*

E90—*Research For Ph.D. Dissertation*

E99—*Resident In Research*

V. Requirements for M.S. and Ph.D. Degrees in Operations Research

A. Satisfactory undergraduate background including calculus through differential equations.

B. Requirements for M.S. degree consist of 36 quarter credit hours of graduate level work including 6–9 hours of thesis in Operations Research. Course content is variable, but will include probability theory and statistics, and at least six courses in Operations Research methods or techniques and advanced mathematics. A final examination is required for the M.S. degree.

C. The Ph.D. program requires a minimum of 3 years (108 quarter-hours) of graduate level work beyond the B.S. degree. Up to 36 quarter-hours of credit are allowed for successful completion of a M.S. degree. The first 2 years of graduate study are normally devoted to course work in mathematics, probability and statistics, Operations Research methods and techniques, and related areas. A comprehensive examination covering major and minor areas of specialization is required before admission to candidacy and the initiation of the Ph.D. research. The thesis must be a significant contribution to existing knowledge in the field of Operations Research, suitable for publication, in part, in a scientific journal.

D. Defense of thesis is required.

Department and Faculty responsible for recommending these degrees: Advanced degrees in Operations Research are conferred by the Graduate School on the recommendation of a committee consisting of one or more of the previously mentioned faculty or on recommendation of the Department of Industrial Engineering and Management Sciences.

A degree in applied mathematics and systems analysis area is also conferred by the Department of Engineering Science with specifically similar requirements.

SCHEDULE OF FUTURE SOCIETY MEETINGS

No.	Dates	Location	Chairman	Deadline for Abstracts
26	October 7–9, 1964 (with TIMS)	Minn.-St. Paul	Paul V. Grambsch*	June 1, 1964
27	May 6–7, 1965	Boston	David M. Boodman	January 1, 1965
28	November, 1965	Houston	James A. Birdwell	
29	May, 1966	Los Angeles	John E. Walsh	

* Please submit abstracts of papers to Dr. Gordon B. Davis, School of Business Administration, University of Minnesota, Minneapolis, Minnesota 55455.

NOTE: Abstracts of papers to be presented at a Society meeting must be submitted at least four months prior to the date of that meeting. Send abstracts to the meeting chairman or to Dr. Paul Stillson (Chairman, ORSA Meeting Committee), 21 Marinero Circle, Tiburon, California.

News and Announcements

MILITARY OPERATIONS RESEARCH SYMPOSIA (MORS)

(*Ed. Note: The following information was abstracted from "The Role of The Military Operations Research Symposia (MORS) in the Operations Research Community," a paper delivered at the 24th National Meeting of ORSA, Seattle, November 7–8, 1963, by* M. C. YOVITS, *Office of Naval Research, Executive Director, MORS. The joint author was* M. N. CHASE, *Combat Operations Research Group; Member, Executive Council, MORS.*)

Purpose

An estimated 5,000 full-time professional scientists work exclusively in military operations research at an estimated D.O.D. expense of $160 million annually. These figures compare to an estimated 1,800 industrial OR workers, a ratio of three military OR workers to one industrial OR specialist. But, two-thirds of the military operations research workers do not identify with an operations research society, nor do they submit their work to the appropriate journals and meetings for review.

This is because 75–80% of the reports in military operations research are classified. And, although many of these classified documents could be presented in allegorical form independently of the military classification problem, the really exciting studies cannot. In addition, many of the problems that could be declassified might very well be of little or no scientific or mathematical interest as such—even though they are of the greatest interest to the military and should be discussed fully by the military operations research community.

So, the purpose behind the development of military operations research symposia is to provide a forum to allow people engaged in *classified* research to discuss the activities in which they are interested. Such forums provide an interchange of ideas, prevent duplication of effort, provide the judgment and motivation of scientific peers, allow for the participation of the operational users—the military officers—and foster the development of students of military operations research.

History

To this end, the first Military Operations Research Symposium, with 83 participants, was held on "Air Defense" in August, 1951, under the sponsorship of the ONR Branch Office in Pasadena. The value of such gatherings was immediately recognized, and the Symposia were continued thereafter, first on a regional basis on the West Coast and then nationally. Attendance at recent Symposia has averaged 400, and to date twelve MORS have been held, with two planned for the near future:

1. Air Defense
2. Methodology

3. Antisubmarine Warfare
4. Combat Control, ASW, and Weapon System Costing
5. ASW, Ballistic Missile Threat, Tactical Analysis, and Weapon System Costing
6. Human Factors and Man-Machine Studies, War Gaming, and Implications of Nuclear Weapons on Military Operations
7. Command and Control, Tactical Analysis, Reliability, Space and Military Operations
8. War Models and Combat Operations
9. Weapon and Support Systems
10. Command and Control
11. Limited War
12. Air Defense
13. Effectiveness of Conventional Weapons
14. Operational Data

Each Symposium consists of several invited papers on the theme of the meeting and a number of contributed papers. In addition there are a number of working groups, which meet concurrently. The working groups generally continue from Symposium to Symposium with about a 50% overlap of 10–20 members. At present working groups are held on the following subjects.

Antisubmarine Warfare
Arms Control and Disarmament
Command and Control
Human Factors
Limited War Research
Logistics
Education in Operations Research for Military Personnel
War Gaming
National Security Planning
Strategic Intelligence

In September 1962 MORS was taken over by the Office of Naval Research in Washington, D.C., in particular, by the Naval Analysis Group, of which DR. M. C. YOVITS is the Director. From 1957 to 1960 MORS was under DR. CHARLES DE PRIMA's chairmanship, and from May 1960 to September 1962 under DR. JAMES E. GARVEY. The first MORS sponsored by ONR Washington was the eleventh, held in April, 1963.

Administrative Organization

The specific guidance for the operation of MORS with regard to program, planning, etc., comes from an Executive Committee of 25 members of major reputation representing the spectrum of military operations research for all services. The members of the Executive Committee rotate, roughly ¼ giving up their membership and being replaced by vote of the existing Executive Committee each year. Thus the Committee is a self-perpetuating body. The members of the Executive Committee currently are:

DR. CLINTON J. ANCKER (*SDC*)
DR. HOWARD M. BERGER (*IDA/WSEG*)
MR. MARTIN N. CHASE (*Tech/Ops., CORG*)

Dr. Glover S. Colladay (*NOTS/China Lake*)
Mr. Harold Davis (*ACDA/WEC*)
Dr. Murray A. Geisler (*RAND*)
Mr. George E. Gompf (*RAND*)
Captain Pleas E. Greenlee, *USN* (*ACDA*)
Prof. Daniel Howland (*Ohio State U.*)
Mr. Ervin Kapos (*OEG*)
Mr. Lewis A. Leake (*PMR*)
Mr. Frederick H. Lund (*NMC/Pt Mugu*)
Mr. Robert J. Miller (*NOL/White Oak*)
Mr. John H. Moss (*RAC*)
Mr. William J. Nemerever (*Boeing*)
Mr. Arthur W. Pennington (*WSEG*)
Mr. Myles Sheehy (*NEL*)
Dr. H. Wallace Sinaiko (*IDA*)
Mr. Arthur Stein (*CAL*)
Dr. John K. Sterrett (*NORAD*)
Mr. Bergen R. Suydam (*IDA/WSEG*)
Mr. Clayton J. Thomas (*AFCOA*)
Dr. Mathews C. Waddell (*APL/JHU*)
Dr. Carroll L. Zimmerman (*Douglas*)
Dr. Marshall C. Yovits, *Executive Director*
Mr. Vance R. Wanner, *Executive Secretary*

Dr. Murray Geisler of RAND is currently Chairman of the Executive Committee.

The nucleus of the Executive Committee is the Executive Council, made up of the Chairman, two other members and the Executive Director, ex-officio.

The actual detailed administration of MORS is accomplished by a Secretariat headed by Mr. Vance R. Wanner who is known as the *Executive Secretary*. The Executive Secretary reports to the *Executive Director*.

MORS Proceedings

A Proceedings is normally published after each Symposium, which is classified *Secret*. The Proceedings are automatically given to the facility of each attendee as part of the registration fee. Procedures are available by which any facility desiring additional copies and satisfying the security and need to know requirements may do so.

These Proceedings provide an effective way in which military operations analysts can achieve reasonably wide publication in the classified field. There is a selection and editorial process by the Program Committee that goes into those papers accepted. The quality of the Proceedings is constantly improving.

Registration

Anyone is eligible to attend MORS who has the proper security clearance (generally Secret) and who has the need to know. This is now being interpreted as working on some Department of Defense operations research contract classified at least *Secret.* Anyone satisfying these criteria who has an interest in MORS and is not already on this list, will be put on the distribution list for information concerning future meetings and proceedings and calls for papers by sending his address to: *Military Operations Research Symposia, Old Post Office Building, 12th and Pennsylvania Avenue, N.W., Washington 25, D. C.*

However, in the interest of keeping the meeting to a manageable size and to maintain a proper balance of attendees the Program Committee and ONR will generally select from among those who desire to attend any particular Symposium. Our general interest is to limit the size of each meeting to a maximum of 350–400 attendees.

It is planned at this time to have two Symposia each year, one in the Spring in the East, and one in the Fall in the West. The 13th MORS will be held the last week in April 1964 at the Industrial College of the Armed Forces in Washington, D. C. on the subject of *The Effectiveness of Conventional Weapons.* The 14th MORS will be held in October of 1964, somewhere in the Western part of the United States, on the general theme of *Operational Data* and their use in operations research studies.

THE INTERNATIONAL FEDERATION OF OPERATIONAL RESEARCH SOCIETIES

According to a recent communication from the Secretary of the Federation, Philip M. Morse, the following actions have now been officially ratified:

- The Foster Society for the 1965–67 triennium will be the *Société Française de Recherche Opérationnelle* (SoFRO), and the officers of the Federation for this period will be MARCEL BOITEUX, *Secretary,* CHARLES SALZMANN, *Deputy Secretary,* and HENRI LAVAILL, *Treasurer.*
- The Swiss and Spanish national operations research societies have been approved for admission as members of IFORS: *Schweizerische Vereinigung für Operations Research* (SVOR), and *Sociedad Española de Investigacion Operativa* (SEIO).
- ORSA will be Host Society for the Fourth International Conference on Operational Research in 1966.
- Application by IFORS for Category C affiliation with the United Nations Education, Scientific, and Cultural Organization (UNESCO): This status obligates IFORS to keep the Secretary General informed of its activities, and to inform its members of relevant UNESCO activities.

The Program Committee for the 1966 conference has the following membership:

MARTIN L. ERNST (US), *Chairman*
ALEC M. LEE (Canada), *Deputy Chairman*
JACQUES BARRACHE (France)
GIUSEPPE POMPILJ (Italy)
KRISTEN NYGAARD (Norway)
H. P. KÜNZI (Switzerland)
WILLIAM S. JEWELL (US)
K. D. TOCHER (UK)

George R. Murray, Jr. (US) will act as the committee's *Executive Secretary*, and three *Corresponding Members* have been appointed:

William B. Kennedy (Australia)
Takehiko Matsuda (Japan)
R. S. Varma (India)

An ORSA site-selection committee consisting of Leslie C. Edie, George R Murray, Jr., and David A. Katcher, *Chairman*, has recommended that the meeting be held during the last half of August at the Massachusetts Institute of Technology, Cambridge, Massachusetts.

Hugh J. Miser
IFORS Representative

OPERATIONAL RESEARCH AND THE SOCIAL SCIENCES

The Operational Research Society of the United Kingdom, with the joint sponsorship of the International Federation of Operational Research Societies, will hold an *International Conference on Operational Research and the Social Sciences* at Gonville and Caius College, Cambridge, England, September 14–18, 1964. There will be sessions on organization and control, the social effects of policies and their measurement, conflict resolution and control, and the systems concept as a common frame of reference.

The fee for the conference, including full board and lodging, will be in the neighborhood of £40. Further information on the conference and registration for it may be obtained from Mrs. Margaret Kinnaird, *Secretary, Operational Research Society, 64 Cannon Street, London E.C.4, England.*

WASHINGTON OPERATIONS RESEARCH COUNCIL (WORC)

This group held a Second War Gaming Symposium, March 16–17, 1964, at The International Inn, Washington, D. C., which was planned to be of special interest to the scientist and military person not an expert in the field of war gaming or simulation. The meeting was unclassified. In addition to a number of invited papers, there was a panel discussion by users of games and simulations, with Robert F. Meier, Johns Hopkins University, *Moderator*. A Proceedings will be published containing complete papers: Murray Greyson, Minneapolis-Honeywell, 1701 Pennsylvania Ave., N.W., Washington, D. C., *Editor*.

The January Meeting of WORC heard Kurt Eiseman discuss "A Generalized Stepping-Stone Solution to the Generalized Transportation Problem and Standard Computer Program," and in February, Dave Hertz delivered a paper on "Risk Analysis for Investment Planning." The special topic for the March meeting was "OR in Developing a Novel Mechanized Letter Sorting System." Bernard M. Levin, Arthur E. Newman, Alan Goldman, and Philip Meyers of the National Bureau of Standards, and Robert Miller of the OR Group, U. S. Post Office Department participated in a panel discussion of the problem.

The WORC Newsletter is published regularly for members. John G. Honig, Minneapolis-Honeywell, is *Editor*.

INTERNATIONAL SYMPOSIUM ON MATHEMATICAL PROGRAMMING

This Symposium will be held at the London School of Economics, July 6–10, 1964, and is sponsored by the *Royal Statistical Society*, the *Operational Research Society*, the *British Computer Society*, the *Institute of Management Sciences* and the *Association for Computing Machinery*. Both theoretical and practical aspects will be covered. The papers will be in English or French. *No* proceedings will be published. *For further details:* MRS. M. KINNAIRD, *Secretary, Operational Research Society, 64 Cannon Street, London E.C. 4.*, to whom applications for tickets should also be made. Attention is drawn to the fact that this Symposium coincides with the City of London Festival and it would therefore be wise to make early hotel bookings.

OPERATIONAL RESEARCH SOCIETY OF INDIA

The Indian Society is proposing to bring out a quarterly publication entitled *OPSEARCH*. Subscriptions for the journal is $5, and for members of fraternal operations research societies, $4 (25 and 20 Sh. respectively). Further information regarding this publication may be obtained from A. RAHMAN, *Secretary, Operational Research Society of India, c/o CSIR, Rafi Marg, New Delhi.* Other officers of this society are: MAJ. GEN. B. D. KAPUR, *President*; PROF. R. S. VARMA, and JAGJIT SINGH, *Vice Presidents*; A. RAHMAN and DR. S. K. GUPTA, *Secretaries*, and BALDEV SINGH, *Treasurer.*

HUNGARIAN BUILDING GROUP

DR. IVAN KÁDÁR, *Director*, has announced the formation of a *Bureau for Computation and Mechanization of Building Administration, Vaczi-ut 4, Budapest, Hungary.* The Bureau publishes a journal in English and other languages, and "is financed mainly by the funds of the Ministry of Building Industry. The Bureau also performs services for other building enterprises and research institutes at a fixed tariff. GORDON SHELLARD, *Secretary of ORSA*, has arranged for an exchange of publications with this group.

PURDUE OPTIMIZATION COURSE

The fifth annual short course in *Mathematical Techniques of Optimization* will be held during the ten-day period June 1–June 11, 1964. Staff includes PROFESSORS LEONARD BERKOWITZ and MARCEL NEUTS, both of Purdue, and DR. ALBERT MADANSKY of the University of California and the RAND Corporation, Santa Monica. Eligibility limited to those who have had calculus, differential equations, and at least one course in statistics. For details: PROFESSOR PAUL H. RANDOLPH, *Division of Mathematical Sciences, Purdue University, Lafayette, Indiana, who is course director.*

NORTHWESTERN SUMMER TRANSPORTATION INSTITUTE

The Second Annual Summer Institute in Transportation for undergraduates and for executive and technical personnel will be held at Northwestern University, Evanston, Illinois, June 22–August 25, 1964. Enrollment in the eight-week program is open to those who have three years of college credits, or the equivalent. Full-time participants will select three of six credit courses offered, plus the required non-credit Seminar in Transportation. Several field trips are included. Tuition for full-time is $468, with a few Fellowships providing for tuition, room and board available to qualified students. For more information: JAMES SLOSS, *Assistant Director of Education, The Transportation Center at Northwestern University, 1818 Hinman Ave., Evanston, Illinois, 60204.*

UNIVERSITY OF MICHIGAN SUMMER CONFERENCES

Each summer the College of Engineering of the University of Michigan offers a series of intensive non-credit courses especially designed for practicing engineers and scientists in rapidly developing fields of technology. Thirty-one such courses will be offered during the summer of 1964.

Two courses are especially designed for operations researh personnel: **1.** *Foundations and Tools for Operations Research and the Management Sciences,* August 10–21, 1964 (ten class days) Fee; $275, W. ALLEN SPIVEY and ROBERT M. THRALL, *Co-Chairmen.* Lecturers: M. L. BALINSKI, S. GOLDBERG, H. O. HARTLEY, and P. WOLFE. Although facility in calculus is not assumed in this session, the course is designed for persons whose bachelor's degree program included a year of calculus. **2.** *Recent Mathematical Advances in Operations Research,* August 10–21, 1964 (ten class days) Fee, $275, EUGENE L. LAWLER and GEORGE MINTY, *Co-Chairmen.* Lecturers: M. L. BALINSKI, R. BELLMAN, P. C. GILMORE, H. O. HARTLEY, G. L. THOMPSON, R. M. THRALL, P. WOLFE, and others. For a complete catalogue describing these courses and others that may be of interest, write *Conference Secretary, Engineering Summer Conferences, West Engineering Building, The University of Michigan, Ann Arbor, Michigan,* or telephone Area Code 313, 663-1511, extension 3562.

M. I. T. SUMMER COURSE

The Massachusetts Institute of Technology announces a two-weeks course entitled *Probabilistic Methods in the Control of Operations* to be given August 31 through September 11, 1964 for interested and qualified persons. The course will be under the direction of PROFESSOR GEORGE P. WADSWORTH, assisted by M. I. T. faculty and staff of the M. I. T. Operations Research Center. Detailed information may be obtained by writing the *Summer Session Office, Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139.*

BALLISTIC MISSILE AND SPACE TECHNOLOGY SYMPOSIUM

The Ninth Symposium on Ballistic Missile and Space Technology, sponsored by the Space Systems Division, Ballistic Systems Division, Air Force Systems Command, will be held August 12–14, 1964 at The U. S. Naval Training Center, San Diego 33, California. Attendance at the Symposium will require a final Secret clearance. For registration and program details, write *Aerospace Corporation, Attention: 1964 Symposium Chairman, P. O. Box 95085, Los Angeles, California, 90045.*

TIMS-ORSA COMBINED MEETING (MINNEAPOLIS)

"The Role of Operations Research/Management Sciences in National Progress" is the topic of the combined meeting of TIMS-ORSA in Minneapolis, Minnesota, October 7–9, 1964. The plan is to introduce a number of review papers, as well as those on special topics. Abstracts for contributed papers should be submitted by June 1, 1964, to the *Chairman for Contributed Papers*, DR. GORDON B. DAVIS, *School of Business Administration, University of Minnesota, Minneapolis, Minnesota, 55455.*

SAN FRANCISCO MEETING OF TIMS (1965)

The 1965 Meeting of the Institute of Management Sciences will be held February 3–5, 1965, at the Jack Tar Hotel, San Francisco. The Meeting Officers are: *General Chairman*, ERNEST KOENIGSBERG, CEIR, Inc., *Program Chairman*, PROF. DANIEL TEICHROEW, Stanford University; *Arrangements Chairman*, BERTRAM RIFAS, P.I.E., Inc., Oakland. Abstracts of contributed papers should be forwarded to PROFESSOR TEICHROEW, *Graduate School of Business Administration, Stanford University, Stanford, California.*

JOURNAL OF APPLIED PROBABILITY

The Applied Probability Trust, in association with the London Mathematical Society, is to publish a new international journal devoted to the applications of Probability Theory to the biological, physical, social and technological sciences. The *Journal* will be issued in two half-yearly numbers forming a volume of about 300 pages per annum, starting in May–June, 1964. It will include 1) review papers surveying a field of Applied Probability; 2) research papers; and 3) short communications.

Subscriptions for the annual volume of the journal are:—For libraries and institutions: $12, for individuals belonging to a recognised scientific society: $8. Further information can be obtained from the *Editor-in-Chief*, DR. J. GANI, *Department of Statistics, The Australian National University, P. O. Box 4, Canberra, Australia.*

MIT MARKETING COURSE

A one week special program on *Operations Research in Marketing* will be held September 8–12, 1964 at the Massachusetts Institute of Technology. Topics to be covered will include stochastic marketing models, design of marketing experiments, the simulation of complex marketing processes, and statistical decision theory. The staff for the program will be PROFESSORS JOHN D. C. LITTLE, RONALD A. HOWARD, ARNOLD E. AMSTUTZ, HENRY J. CLAYCAMP, and DR. JEROME D. HERMITER. Further information about the program can be obtained from the *Director of the Summer Session, Room 7-103. Massachusetts Institute of Technology, Cambridge 39, Massachusetts.*

PERSONALS

DR. HARRY I. ANSOFF has been named Professor of Industrial Administration, Carnegie Tech. PROF. ANDREW S. SCHULTZ, JR., has been named acting dean of the College of Engineering, Cornell. EDWARD LEYMAN has been appointed Director of the Information Systems Division, Herner and Company, Washington, D. C. GORDON J. CROOK has been promoted to operations research officer, Chase Manhattan Bank. FLOYD HILL has been appointed head of the Washington Project Department, Cornell Aeronautical Laboratory, Inc. IRVING OSCAR has joined the Research and Analysis Division of Booz, Allen Applied Research Inc. DR. LESTER R. FORD has joined the Defense Research Corporation of Santa Barbara, California, as Director of the Mathematics Group. DR. GEORGE H. MILLY has been appointed as vice president of the Travelers Research Center, Hartford, Connecticut. REINE A. MERIKALLIO has been transferred to the Communications Systems Department of the IBM Federal Systems Division in Bethesda, Maryland, in charge of scientific and simulation programming. DR. RICHARD A. CONNEL has been named senior physicist, and JOHN E. HOSFORD has been named associate operations analyst, Midwest Research Institute, Kansas City. DR. E. LEONARD ARNOFF and KENNETH S. CALDWELL have been appointed principals, Ernst & Ernst NORMAN E. COTTRELL has been named Director of Marketing, Ernest E. Blanch & Associates, Inc., Kensington, Maryland. EDWARD A. SILVER has joined the Operations Research Group of A. D. Little, Inc., Cambridge. DONALD Y. BARRER is head of the Operations Analysis Department, Aerospace Corporation, and ROBERT M. CARLISLE has been appointed to the technical staff of the systems analysis and evaluation section. PATRICK J. ROBINSON is Associate Director .of Research of the Marketing Science Institute, Philadelphia, Pennsylvania. JEAN G. TAYLOR has joined the professional staff of the Institute for Defense Analysis, Washington, D. C., and ALFRED BLUMSTEIN is on leave as visiting associate professor at Cornell University for the 1963–4 academic year.

The following have been reported as joining the organizations listed below:

Center for Naval Analysis: LESTER K. ARQUETTE, JR., ROBERT M. NATKIN, DAVID B. NEWMAN, WILLIAM H. WOOD, JR., DR. H. KENNETH GAYER, W. DONALD WEIR.

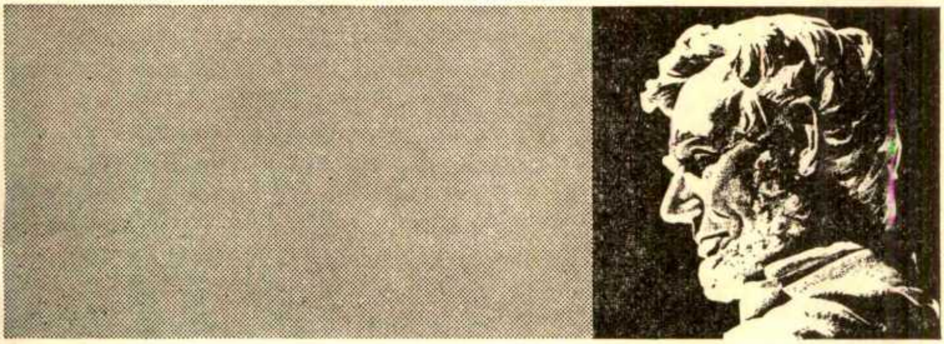
Operations Research Incorporated: LEO J. FITZGERALD, ROBERT C. FERBER, CARL M. KOCH, DANIEL D. SEGAL, MICHAEL W. PULSCAK, RICHARD H. SCHNELL, ALAN O. MANN, J. TREVOR MCINTYRE, DANIEL BURR JONES, P. CRAIG BOGLEY, MARVIN C. GECHMAN, GEORGE G. BEEKER, JR., JOEL E. TUMARKIN.

Research Analysis Corporation: LEONARD W. STEARNS, ROBERT E. PUGH, ROBERT A. CHARRON, DR. RUFUS C. LING, DR. JOHN W. BRACKETT, ARNOLD J. MELTSNER, J. K. HART, JOHN J. SURMEIER, STEPHEN B. FORMAN, MICHAEL S. MORRIS, BRIG. GEN. ROBERT H. WILLIAMS (USMC Ret.), DR. GEORGE K. CHACKO, LT. COL. WILBUR O. MILLER, JR , (USA Ret.), ALBERT M. BOTTOMS, WILLIAM CONNERAT, FLETCHER BARTHOLOMEW. FRED W. WOLCOTT has been elected Vice President for Operations, and HUGH M. COLE Vice President for Operations Analysis at RAC.

GLEN E. GHORMLEY, management scientist, passed away in his sleep, October 19, 1963, in Los Angeles, where he resided at 5023 Oaknoll Avenue.

DR. LYNN HAMILTON RUMVAUGH, 60, long a senior staff member and research director at the Research Analysis Corp. (RAC), the former Operations Research Office of the Johns Hopkins University, died March 11, at his home in Bethesda, Maryland.

Operations Research and IDA



Washington is the decision-making center of the free world. In that center, IDA functions as a scientific adviser to the Joint Chiefs of Staff and the Director of Defense Research and Engineering as well as other key offices in the Pentagon. The operations research activities of our organization are centered in the Weapons Systems Evaluation Division, but extend also to the Research and Engineering Support Division and the Economic and Political Studies Division. In seeking optimum solutions we address ourselves not only to the technical performance of competitive weapons systems, but also to their political and economic implications, the strategy they would permit or demand, logistics problems in their use, feasibility, and probable lifetime. * In a world in which the complexities and exigencies of our nation's defense and foreign policy continue to increase and grow more critical, IDA's programs must also continue to expand. We invite qualified operations research analysts, scientists and engineers to investigate both short term (two to three years) and permanent appointments. Respondents should possess an advanced degree, and those valuable intangibles called 'creativity' and 'originality.' * A career at IDA can present a challenge of satisfying proportions and provide a reward of substance. Write us; we may well have mutual interests. * Institute for Defense Analyses, 1666 Connecticut Avenue, N.W., Washington 9, D. C.

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A MESSAGE TO SCIENTISTS AND ENGINEERS

I am addressing this message to scientists, engineers, and analysts who would like to be associated with one of the country's leaders in operations research, systems analysis, and computer programming. TECH/OPS undertook its first O. R. program ten years ago. Since that time we have completed over two hundred research programs in weapons effects, communications, war gaming, logistics, field experimentation, command and control systems, cost-effectiveness, meteorology, and other fields too numerous to mention.

At the present time over half the effort of the Company is in the system and operations research sciences. Research offices are maintained at Fort Belvoir, Virginia; Washington, D. C.; Fort Monroe, Virginia; Fort Benning, Georgia; Burlington, Massachusetts; and Fort Lee, Va.

1964 promises to be a rapidly expanding year in O. R. for TECH/OPS. Positions are available at all TECH/OPS locations. Among them are several managerial opportunities. I would like to extend a cordial invitation to readers of JORSA to meet with our staff to review our present programs, our plans for the future, and —most important—to learn how a position at TECH/OPS can contribute to your professional growth in the system science field. A few of our openings are described on the facing page.

Donald W. Meals

DONALD W. MEALS
Vice President—System Sciences

TECHNICAL OPERATIONS Research tech/ops

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POSITIONS AVAILABLE IN TECH/OPS SYSTEM SCIENCES DIVISION

CORG

Located at Fort Belvoir, Virginia (near Washington, D. C.) with field offices at Fort Benning, Georgia, and Fort Lee, Virginia, CORG provides scientific studies to assist senior Army planners in determining how the Army of the Future will be organized and equipped, and how it will fight.

A number of staff appointments are available for operations research oriented scientists with backgrounds in the physical or behavioral sciences and relevant practical experience. Although most of these positions require advanced degrees and several years of experience, there are openings for well-qualified individuals at all levels.

Inquiries for CORG should be directed to:

Mr. Martin N. Chase, Director
Combat Operations Research Group
P. O. Box 116 Fort Belvoir, Virginia.

WASHINGTON RESEARCH CENTER

Located in Georgetown section of Washington, TECH/OPS' the Washington Research Center is presently providing scientific support for military operations. Among WRC's projects are the computerized simulation of global and limited warfare and the responsibility for programming 473L—a large-scale command and control system for Headquarters, Air Force. Several senior and intermediate positions are available for scientists with backgrounds in military operations research or experience in programming of large-scale systems.

Inquiries for WRC should be directed to:

Mr. Fred Howells, Director
Washington Research Center
3600 M Street, N. W. Washington 7, D. C.

TRAG

The Technical Research Advisory Group (TRAG), located at historic Fort Monroe, Virginia, is seeking qualified systems analysts and computer programmers to develop a large-scale computer system. A minimum of two years' experience in the design of large-scale computer systems and one year's experience in programming medium and large-scale computer systems are required.

Inquiries for TRAG should be directed to:

Dr. Richard Powers, Director
TRAG Box 37 Fort Monroe, Virginia

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Managing Editors **W. Krelle, H. P. Künzi**

Published 1962:

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By **Hans Paul Künzi,** Professor an der Universität Zürich and **Wilhelm Krelle,** Professor an der Universität Bonn
With Cooperation by Werner Oettli, Zürich

With 18 figures. XVI, 221 pages (in German) 8vo. 1962 Cloth $9,50

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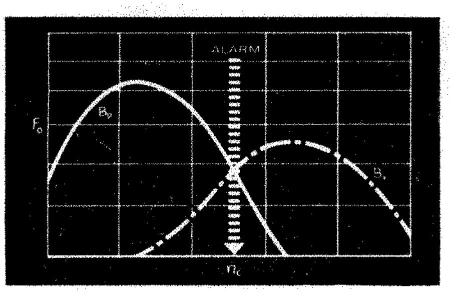

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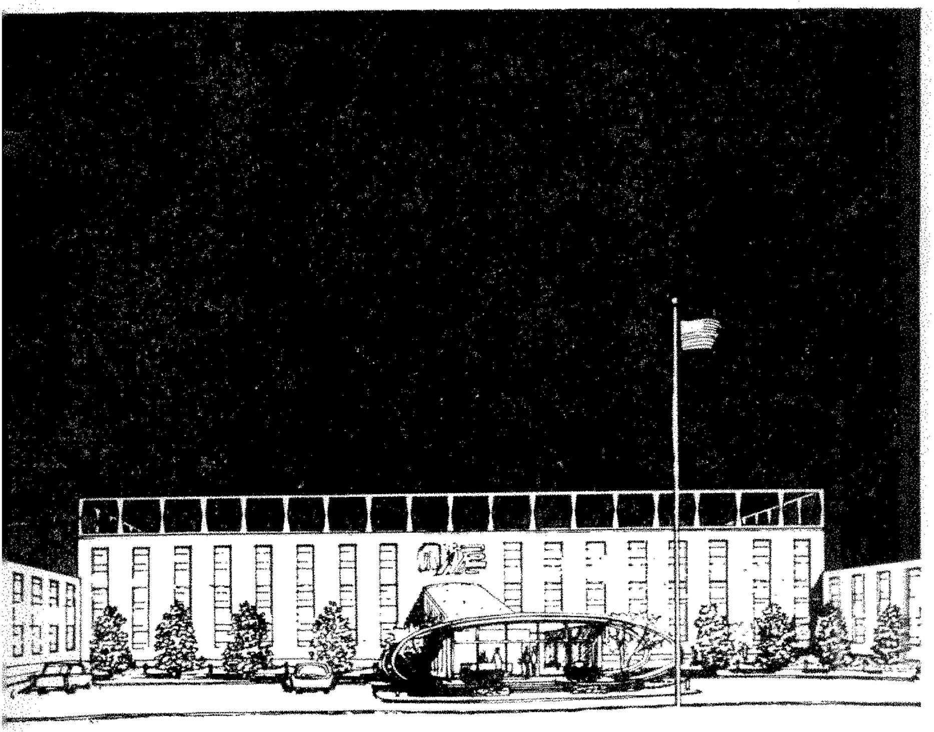

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Journal of
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Volume 59 **March 1964** **Number 305**

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MANUSCRIPTS for publication and Letters to the Editor should be submitted to the Editor of the SOCIETY, either directly or through one of the Associate Editors. Each MS is in general sent to two referees, and from two to four months are ordinarily required for this refereeing process. If a paper is submitted to an Associate Editor, he will arrange to have it refereed before forwarding it to the Editor.

Manuscripts must be double-spaced throughout (including abstract, footnotes, subsidiary matter, tables, and references), with the original in typewritten or equally legible form. Furnishing a complete, legible, duplicate copy accelerates the process of refereeing, but is not mandatory. The style of the JOURNAL should be meticulously followed in copy preparation.

References should be numbered consecutively and grouped at the end of the paper; for journal references give at least author, volume, page, and year; for book references give at least author, title, publisher, city, and year.

In mathematical expressions, authors are requested to use the solidus whenever possible in preference to built-up fractions, to write complicated exponentials in the form exp( ), to avoid subscripts or superscripts *on* subscripts or superscripts, and in general to minimize unusual or expensive typographical requirements. Subscripts and superscripts must be shown large and clear; Greek letters and unusual symbols should be labeled on first occurrence, as should subscript 'zero,' to distinguish it from 'oh.' Whether each letter is capital or lower case must be unambiguous. Equation numbers must be *at the right.*

Figures must be drawn in black ink on white paper in a form suitable for photographic reproduction. Lettering must be of uniform size and sufficiently large to be legible when the figure is reduced to final size. Figures should be designated by arabic numbers, and legends for all figures must be typed on a single separate sheet rather than placed on the drawings.

Material that has already been published in books or recognized journals, or submitted for such publication elsewhere, is *not* acceptable for publication, but *review articles*, so labeled, are solicited.

Each article representing original research must be accompanied by an *Abstract* of from 100 to 200 words, to be printed at the head of the article. The abstract should summarize the principal results and conclusions. Articles representing original research should be kept as brief as possible, consistent with clarity; arguments already available in other published work should be merely cited, not repeated; references to related previous work should be reasonably complete.

Manuscripts not conforming closely to the above instructions will not be refereed or considered for publication until suitable copy is furnished.

WEDNESDAY MAY 27, 1964

ROOM	TIME BLOCK 1		2		3		4	5	EVE
	8:00–10:00		10:15–12:15		2:00–3:30		3:45–5:15	5:15–5:30	6:00 8:30
a	REGISTRATION	COFFEE BREAK: Courtesy of Computing Devices of Canada	SIMULATION	LUNCH: CORS Presidential Address	SIMULATION (cont'd)	BREAK	SIMULATION (cont'd)	▨	Wine and Cheese Tasting Party St. Helen's Island (transportation to and from hotel provided)
b			REAL-TIME CONTROL SYSTEMS		REAL-TIME CONTROL SYSTEMS (cont'd)		REAL-TIME CONTROL SYSTEMS (cont'd)	ORSA Business Meeting	
c			THEORY AND SPECIAL MODELS		THEORY AND SPECIAL MODELS (cont'd)		SATELLITES	▨	
d			TEXTILE INDUSTRY		ORSA TRANSPORTATION SCIENCE SECTION		ORSA TRANS. SCI. (cont'd) TRANS. SCI. SEC. Business Meeting	▨	
e			▨		COST-EFFECTIVENESS WORK SESSION		COST-EFFECTIVENESS WORK SESSION	▨	

THURSDAY MAY 28, 1964

ROOM	TIME BLOCK 1		2		3		4	Evening
	9:00–10:30		10:45–12:15		2:00–3:30		3:45–5:15	
a	MILITARY COST ANALYSIS	COFFEE BREAK: Courtesy of IBM Co Ltd	MILITARY COST ANALYSIS (Cont'd)	LUNCH (No Luncheon function scheduled)	MILITARY COST ANALYSIS (Cont'd)	BREAK	MILITARY COST ANALYSIS (Cont'd)	6:00 p m Reception 7:00 p m BANQUET Queen Elizabeth Hotel Speaker: Dr. O. M. Solandt "SOVIET RESEARCH
b	THE PRACTICE OF O.R.		THE PRACTICE OF O.R. (Cont'd)		MATHEMATICAL BIOLOGY AND O.R.		MATHEMATICAL BIOLOGY AND O.R. (Cont'd)	
c	MATHEMATICAL PROGRAMMING		MATHEMATICAL PROGRAMMING (Cont'd)		MATHEMATICAL PROGRAMMING (Cont'd)		MATHEMATICAL PROGRAMMING (Cont'd)	
d	ORSA TRANSPORTATION SCIENCE SECTION		ORSA TRANSPORTATION SCIENCE SECTION (Cont'd)		TRANSPORTATION		TRANSPORTATION (Cont'd)	

FRIDAY MAY 29, 1964

ROOM	TIME BLOCK 1		2		3		4	
	9:00–10:30		10:45–12:15		2:00–3:00		3:45–5:15	▨
a	CASE HISTORIES	COFFEE BREAK: Courtesy Remington Rand, Univac Div.	CASE HISTORIES (Cont'd)	LUNCH: ORSA Presidential Address	SPECIAL TOPICS	BREAK	CORS BUSINESS SESSION	▨
b	STRATEGY OF INFORMATION RETRIEVAL		STRATEGY OF INFORMATION RETRIEVAL (Cont'd)		INFORMATION RETRIEVAL		▨	▨
c	QUEUING		QUEUING (Cont'd)		SYSTEMS		DECISION	▨
d	MILITARY O.R.		PLANNING		PLANNING (Cont'd)		PLANNING (Cont'd)	▨

PERSONAL SCHEDULE.

DAY	TIME BLOCK					
	1	2	3	4	5	EVE
W						
T						
F						

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NOTES

1. As a courtesy to the other participants, please do not enter or leave the rooms while sessions are in progress. Breaks of 15 min. are provided in mid-morning and mid-afternoon for changing rooms.

2. All rooms are on the Convention floor. They are identified by special signs as

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3. Abstracts are identified by Code (below) and are listed in the program in the sequence

Day
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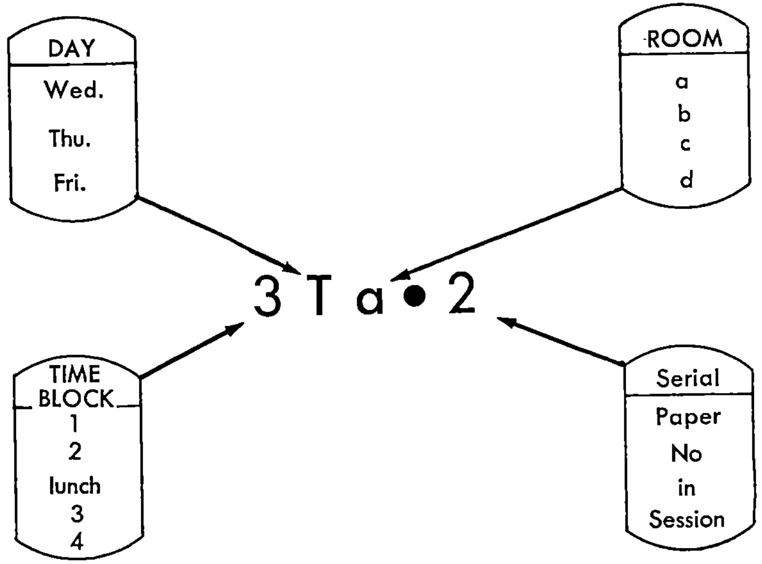
4. Invited papers are denoted by an asterisk (*).



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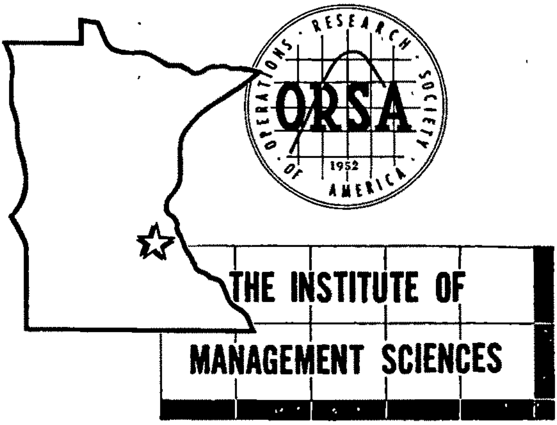
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BULLETIN

OF THE

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Supplement 2 OPERATIONS RESEARCH Volume 12, 1964

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The Minneapolis, Minnesota Meeting

1964 TIMS-ORSA
Joint National Meeting

REGISTRATION INFORMATION

The Institute of Management Sciences and The Operations Research Society of America will hold their 1964 Joint National Meeting on October 7–9 at the Leamington Hotel in Minneapolis, Minnesota. Since the meeting occurs at the peak of the 1964 National Election Campaign, it is both desirable and timely to select a theme that will fit in with this significant event. Accordingly, we have selected as the leading theme: THE ROLE OF OPERATIONS RESEARCH AND MANAGEMENT SCIENCE IN NATIONAL PROGRESS.

To assure that the breadth of the theme will be satisfied, the selection of session topics is based on the Cabinet Departments of the Federal Government, supplemented by some of the separate key agencies. The subject matter coverage in each session is defined to assure representation in speakers and point of view from the three major sectors of research in the country: government, industry, and the university.

The scope of the topics suggests that a liberal sprinkling of review papers will help to achieve breadth in terms of what has been done, and some "think pieces" on the future trends, unsolved problems, and interesting areas for future research. In addition to the 16 sessions for invited papers, there are 4 concurrent sessions for contributed papers.

Those who have visited the Twin Cities in October know that this is perhaps the most enjoyable time of the year from the standpoint of weather and scenery. The autumn coloring provides a beautiful backdrop for these two cities of lakes.

The combination of the fall climate, the Tyrone Guthrie Theatre, and our outstanding women's program, make for an experience for your ladies which will be as rewarding to them as the professional program will be to you. We hope that they will accompany you.

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The registration desk in the Dakota Room of the Hotel Leamington will be open in accordance with the following schedule:

Tuesday,	October 6:	4:00 p.m. to 9:00 p.m.
Wednesday,	October 7:	8:00 a.m. to 5:00 p.m.
Thursday,	October 8:	8:00 a.m. to 5:00 p.m.
Friday,	October 9:	8:00 a.m. to 1:00 p.m.

Fees for Registration are:

Member	$10.00	Luncheons	$3.00
Non-Member	$12.00	Banquet	$6.00
Student	$2.00	Mixer	Free
Women's Program	$10.00		

A meeting registration card is enclosed.

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The Hotel Leamington has reserved ample rooms for the meeting, and they will arrange for any necessary additional rooms with the Curtis Hotel just across the street.

The hotel is at Tenth Street and Third Avenue South. Room rates range from $8.50 to $16.00, for single occupancy, and from $12.50 to $22.00 for double occupancy. A hotel registration card is enclosed. The hotel provides free parking for all guests registered at the hotel. The parking lot entrances are off Tenth Street (one-way southeast) and Eleventh Street (one-way northwest).

The Minneapolis-St. Paul International Airport is nine miles south and east from the hotel. The limousine fare is $1.40 per person, and the taxi fare is about $3.50 per group. Cab fares from the hotel to the downtown area (four to six blocks) will run around 55 to 65 cents.

General Information

Firms desiring to post recruiting notices may do so on a board to be provided in the registration room, which is the Dakota Room of the hotel. Notices must not exceed 8½″ x 11″ in size and must be forwarded to the *Registration Chairman*, DANIEL B. MAGRAW, *℅ Gold Bond Stamp Company, 12715B State Highway 55, Minneapolis, Minnesota 55427*, for clearance and posting.

There will be a book display. Authors and publishers desiring to display their books may arrange to do so through DR. RAYMOND E. WILLIS, *School of Business Administration, University of Minnesota, Minneapolis, Minnesota 55455.*

Copies of Papers

Please write directly to authors for copies of the papers in which you are interested. Neither the Secretary, Program Chairman, *Bulletin* Editor nor other officials of ORSA or TIMS has copies for distribution.

Program of Women's Events

MINNEAPOLIS is happy to welcome the women of TIMS-ORSA to this convention. Our women's committee will do everything possible to insure your entertainment. We are your hosts—help us to do a good job by letting us know how we can best serve you.

WEDNESDAY—October 7

8:30 a.m.	Continental Breakfast Ladies' Hospitality Headquarters
10:30 a.m.	Buses leave—3rd Avenue Entrance, Hotel Leamington for Old Log Theater
11:30 a.m.	Lunch at Old Log Theater
12:30 p.m.	Play to be announced Old Log Theater Company
5:30 p.m.	MIXER—Hotel Leamington Delegates and Wives

THURSDAY—October 8

8:30 a.m.	Continental Breakfast Ladies' Hospitality Headquarters
10:00 a.m.	Buses leave—3rd Avenue Entrance, Hotel Leamington for Twin Cities Women's Association Minneapolis Symphony Orchestra (WAMSO) Tour
12:00 Noon	Lunch at Lowell Inn in Stillwater
7:00 p.m.	Banquet—Hotel Leamington Delegates and Wives

FRIDAY—October 9

8:30 a.m.	Continental Breakfast Ladies' Hospitality Headquarters Free time for shopping to 2:00 p.m.
2:00 p.m.	Champagne Tea

The ladies' fee of $10.00 covers all the above meals, gratuities, registration, transportation and entertainment for the entire three days, except banquet.

Concurrent Events in The Twin Cities

The Second Season of the Minnesota Theatre Company at the Tyrone Guthrie Theatre closes on October 10. The TIMS-ORSA Committee is holding a limited number of seats for each of the final performances. They will be assigned on a first-come, first-served basis.

Wednesday, October 7—Volpone	$3.50
(The registration card incorrectly states "The Glass Menagerie" for Wednesday October 7.)	
Thursday, October 8—The Glass Menagerie—	$3.50
Friday, October 9—Henry V—	$3.50
Saturday, October 10—St. Joan, Matinee—	$3.50
—Volpone, Evening—	$3.50, $5.00

We must know the number of reservations by September 16. If you wish to attend any of these performances, please indicate this on the meeting registration card.

The Minnesota Gophers meet the Northwestern Wildcats in an intercollegiate football game Saturday afternoon, October 10. The Minnesota Vikings play the Detroit Lions in a professional football game on Sunday, October 11. The Committee is holding a small block of seats for each of these games. They will be assigned on a first-come, first-served basis. If you wish to attend either of these games, please indicate this on the meeting registration card.

If you expect to stay over Saturday or Sunday for any of the events listed above, we strongly recommend an individual letter to the hotel requesting a written confirmation of your reservation.

THE COMMITTEE FOR THE MINNEAPOLIS MEETING

Co-General Chairmen	Murray A. Geisler *The RAND Corporation* Paul V. Grambsch *University of Minnesota*
Chapter Chairman, June, 1963 to June, 1964 Registration	Daniel B. Magraw *Gold Bond Stamp Company*
Chapter Chairman, June, 1964 to June, 1965	James C. Grace *General Mills, Inc.*
Treasurer	Norman E. Albrecht *Investors Diversified Services*
Contributed Papers	Gordon B. Davis *University of Minnesota*
Historian	Gene D. Gross *Cargill, Incorporated*
Printing	James A. Hummel *Data Management, Inc.*
Women's Activities	Irene D. Kreidberg *UNIVAC*
Arrangements	Henry A. Montillon *Jensen Printing Company*
Functions	Richard J. Potter *Automated Systems, Inc.*
Book Display	Raymond E. Willis *University of Minnesota*
Rooms	Wesley F. Rydin *Bay State Milling Company*
Publicity	D. H. Wentworth *IBM Corporation*
Program	Murray A. Geisler, *Chairman* Richard L. Van Horn Raoul J. Freeman Allen S. Ginsberg Philip J. Kiviat Robert J. Wolfson *The RAND Corporation*

SESSION CHAIRMEN

A.1 Perkins Pedrick
A.2 Gordon B. Davis
A.3 Edward Weinthaler
A.4 Nicholas A Glaskowsky

B.1 Kenneth J. Arrow
B.2 William J. Horvath
B.3 Peter V. Norden

C.1 Roy Radner
C.2 Ithiel de Sola Pool
C.3 Nate Maccoby
C.4 Richard Rothery

D.1 Charles J. Zwick
D.2 Allen B. Richards
D.3 Charles C. Holt

E.1 George J. Feeney
E.2 Dale E. Oyster
E.3 Roger R. Crane

F.1 William Platt
F.2 Gifford H. Symonds
F.3 Edward W. Cushen

PROGRAM
1964 TIMS-ORSA JOINT

SESSIONS AND LOCATION	WEDNESDAY, OCTOBER 7
Dakota Room	Registration: 8:00-5:00
Morning Sessions—9:00-12:00	
Michigan Room	A.1. Military, Space and Air Transportation
Minnesota Room	A.2. Industrial Applications
Iowa Room	A.3. O.R. Techniques
New York Room	A.4. Education, Welfare and Public Policy
Luncheon—12:15-1:45 Twin Cities Room	Speaker: Louis T. Rader, *Vice President,* *General Electric Company*
Afternoon Sessions—2:00-5:00	
Michigan Room	B.1. Foreign Policy & Affairs
Minnesota Room	B.2. Health
Iowa Room	B.3. Research & Development
EVENING ACTIVITIES	5:30-7:30—MIXER, Lincoln Room 8:00—TIMS Council Meeting —ORSA Business Meeting

TUESDAY OCTOBER 6 ACTIVITIES:
Registration: 4:00-9:00 P.M.—Dakota Room
6:30-9:00 P.M.—TIMS College on Management Control Systems
8:00 P.M.—ORSA Council Meeting

PLAN
NATIONAL MEETING

THURSDAY, OCTOBER 8	FRIDAY, OCTOBER 9
Registration: 8:00–5:00	Registration: 8:00–1:00
C.1. Economic Growth C 2. Communications C.3. Organizational Behavior C.4. Transporation Science Section of ORSA	E.1. Individual Behavior E.2. Space E.3. Trade
Presentation: Lanchester Prize Speaker: DAVID B. HERTZ, *President, TIMS*	Speaker: WILLIAM G. SHEPHERD, *Vice President, University of Minnesota*
D.1. Transporation D.2. Agriculture D.3. Fiscal Policy	F.1. Education F.2. Natural Resources F.3. Defense
5:00–6:15—TIMS College on Research & Development 5:00–6:15—TIMS College on Planning 7:00 BANQUET, Hall of States	

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Zuckerman, J. V.: **A4f**

PROGRAM

1964 TIMS-ORSA JOINT NATIONAL MEETING

October 7-9, 1964

Leamington Hotel

Minneapolis, Minnesota

WEDNESDAY MORNING, OCTOBER 7

9:00 a.m.–12:00 Noon *Session A*

1, 2, 3, and 4 are in concurrent sessions

A. 1. CONTRIBUTED PAPERS ON APPLICATION OF O.R. TO MILITARY, SPACE AND AIR TRANSPORTATION PROBLEMS

Location: MICHIGAN ROOM

Chairman: PERKINS PEDRICK, *Logistics Management Institute, Washington, D. C.*

- a. **Effective Reliability for Manned Space Systems,** K. A. FREDERIKSEN, *Douglas Aircraft Company, Inc., Huntington Beach, California*
- b. **Selection of Scientific Payloads for Deep Space Exploration,** JOHN C. DYER, *Avco Corporation, Wilmington, Massachusetts*
- c. **Space Station Operational Availability Model with Cost Constraints,** D. R. JACKSON, A. H. RAMQUIST, AND R. A. HOLTZ, *The Martin Company, Denver, Colorado*
- d. **The Formulation of Safety Policies for Launchings of Missiles and Space Vehicles,** LEWIS A. LEAKE, *Research Analysis Corp., McLean, Virginia*
- e. **Aircraft Landing Rates for Random vs. Controlled Arrivals: A Comparison Based on Probabilties of Missed Approach,** R. V. MORSE, AND T. W. CONNOLLY, *Control Technology, Inc., Princeton, N. J.*

f. **Analysis of Sequencing and Scheduling Methods for an Automated Air Traffic Control System,** M. W. HANS, AND A. S. JACKSON, *Control Technology, Inc., Long Beach, Cal.*

g. **Target Damage Assessment: A Comparison of Two Strategies,** H. C. SEBRING, *General Electric Company—Missile and Space Division, Philadelphia, Pennsylvania*

h. **Metri—Theory and Concept,** WILLIAM J. HUBER, *Clark, Cooper, Field & Wohl, Inc., New York*

i. **Metri—A Structured Approach to Management Information Systems,** DANIAL J. AUSTIN, *Clark, Cooper, Field & Wohl, Inc., New York*

j. **Computer-Assisted Simulation of Supply and Related Systems,** JIMLEE R. KEMPER, *Technical Operations Research—Combat Operations Research Group, Fort Lee, Virginia*

k. **A Budget Model for Procurement of Army Equipment,** CHARLES S. MATHENY, *U. S. Army, Radford, Virginia*

l. **Some Uses and Limitations of Cost-Effectiveness Analysis in Military Decision-Making,** WILLIAM GRODOWITZ, *Headquarters U. S. Air Force, Washington 25, D. C.*

m. **Multi-Level Inventory Systems: The Case of Spare Aircraft Engines,** DJOERD HOEKSTRA, *U. S. Army—Frankford Arsenal, Philadelphia, Pennsylvania*

A. 2. CONTRIBUTED PAPERS ON INDUSTRIAL APPLICATIONS OF OPERATIONS RESEARCH

Location: MINNESOTA ROOM

Chairman: GORDON B. DAVIS, *University of Minnesota, Minneapolis, Minnesota*

- a. **Developing a Sellout and Returns Policy for the Distribution of Newspapers,** NICHOLAS J. RADELL, *Cresap, McCormick & Paget, Chicago, Illinois*
- b. **Balancing Accuracy and Simplicity in Determining Reorder Points,** JOSEPH A. HUNT, *Ernst and Ernst, Cleveland, Ohio*
- c. **The Economic Sizing of Warehouses—A Comparison of Evaluation Models,** CHARLES E. HANCOCK AND H. F. KRAEMER, *General Mills, Minneapolis, Minnesota*
- d. **Results of Computer Simulation of Trading in May Wheat Using a Triple Exponential Smoothing Model,** W. SIEGEL AND A. GUGGENHEIM
- e. **Adaptation to Production Innovation: A Model,** NICHOLAS BALOFF, *University of Chicago, Chicago, Illinois*
- f. **An Analytical Concept for the Selection, Flow, and Transference of Technology in a Large Electronics/Aerospace Firm,** ROBERT R. KLEY, *The Bendix Corporation, Ann Arbor, Michigan*
- g. **Measures of Capital Investment in Professional Knowledge,** J. MORLEY ENGLISH, *University of California, Los Angeles, California*
- h. **Research Project Selection: Where We Stand,** NORMAN R. BAKER AND WILLIAM H. POUND, *Northwestern University, Evanston, Illinois*
- i. **Playing the Profit Edge in Planning Research and Development Expenditures,** PAUL E. WEAVER, *The Service Bureau Corporation, New York, New York*
- j. **Regression Analysis: A Tool for Costing and Budgeting,** M. J. O'CALLAGHAN, *3M Company, Hutchinson, Minnesota*

A. 3. CONTRIBUTED PAPERS ON OPERATIONS RESEARCH TECHNIQUES

Location: IOWA ROOM

Chairman: EDWARD WEINTHALER, JR., *Touche, Ross, Bailey & Smart, San Francisco, California*

a. **Personnel Assignment Decisions,** WILLIAM R. KING, *Case Institute of Technology, Cleveland, Ohio*

b. **A Heuristic Approach to the Location of Multiple Facilities to Serve an Area,** V. CLAYTON LAFFERTY, *Midwest R & D, United Parcel Service, Chicago, Illinois*

c. **The Multifacility Production-Distribution Problem with Nonlinear Production Costs,** J. FRANK SHARP, *Rutgers, The State University, New Brunswick, New Jersey*

d. **Programming by Questionnaire,** ALLEN S. GINSBERG AND HARRY M. MARKOWITZ, *The RAND Corporation, Santa Monica, California*

e. **Establishing Techniques to Determine the Quality of Business Measurements,** ERNEST H. WINWURM, *DePaul University, Chicago, Illinois*

f. **Directed Network Operating Cost and Design Criteria,** R. B. McCLELLAN, *Canoga Park, California*

g. **The Incorporation of Step Functions and Ramp Functions into a Linear Programming Model,** B. ALVA SCHOOMER JR., *Arthur D. Little, Inc., Cambridge, Massachusetts*

h. **A Confidence Interval Estimate for System Availability,** HAROLD I. JACOBSON, *The Boeing Company, Seattle, Washington*

i. **Analysis of Decisions with Incomplete Knowledge of Probabilities,** PETER C. FISHBURN, *Research Analysis Corporation, McLean, Virginia*

j. **Time Development of Stochastic Systems,** HERBERT B. ROSEMAN, *The Mitre Corporation, Bedford, Massachusetts*

k. **Physical Systems Analysis of Socio-Economic Situations,** J. B. ELLIS, *University of Waterloo, Waterloo, Ontario, Canada*

l. **Optimal Tracking of an Unknown Parameter Randomly Shifting in Gaussian Noise,** MELVIN HINICH, *Carnegie Institute of Technology, Pittsburgh, Pennsylvania*

A. 4. CONTRIBUTED PAPERS ON APPLICATION OF O.R. TO EDUCATION, WELFARE AND PUBLIC POLICY

Location: NEW YORK ROOM

Chairman: NICHOLAS A. GLASKOWSKY, JR., *University of Minnesota, Minneapolis, Minnesota*

a. **Decisions Under Uncertainty Involving Extremely Large Numbers of Possible Strategies and States of the World,** MARK ALFANDARY-ALEXANDER, *United States Atomic Energy Commission, Washington, D. C.*

b. **A General Computer Model for Spatial Diffusion Processes,** FORREST R. PITTS, *University of Oregon, Eugene, Oregon*

c. **Systems Evaluation of Transportation Planning Procedures,** V. K. HANDA AND W. A. MCLAUGHLIN, *University of Waterloo, Waterloo, Ontario, Canada*

d. **Models of Commercial Bank Decision Making, and Their Interrelatedness with Monetary Policy,** EDWARD SUSSNA, *University of Pittsburgh, Pittsburgh, Pennsylvania*

e. **Determining the Optimal Number of Volumes for a Library's Holdings,** R. W. TRUESWELL, *University of Massachusetts, Amherst, Massachusetts*

f. **The Diplomat, International Economist and International Businessman of the Future: His Information Environment,** JOHN V. ZUCKERMAN, *University of Southern California, Los Angeles, California*

g. **Management Sciences and Ethics,** GEORGE R. DESI, *Westinghouse Electric, Baltimore, Maryland*

h. **Nonpartisan Political Redistricting by Computer,** SIDNEY W. HESS AND J. B. WEAVER, *Atlas Chemical Industries, Inc., Wilmington, Delaware;* AND H. J. SIEGFELDT, J. N. WHELEN AND P. A. ZITLAN, *E. I. duPont & Co., Inc., Wilmington, Delaware*

i. **The Role of Mathematical Models in Educational Research,** ROGER G. SCHROEDER AND GUSTAVE J. RATH, *Northwestern University, Evanston, Illinois*

j. **Long Range Planning in Mental Health,** JEROME E. SCHNEE AND ROBERT J. HUNTER, *Smith Kline & French Laboratories, Philadelphia, Pennsylvania*

k. **Employment Programming and Education Programming,** JOHN S. MACDONALD, *United Nations, New York, New York*

l. **Solutions for Optimal Designs of Stochastic Learning Experiments,** ROBERT E. DEAR, *System Development Corp., Santa Monica, California*

12:15–1:45 TWIN CITIES ROOM

LUNCHEON

Speaker: LOUIS T. RADER, *Vice President*
General Electric Company
Subject: **Road Blocks To Progress**

WEDNESDAY AFTERNOON, OCTOBER 7

2:00 p.m.–5:00 p.m. ***Session B***

1, 2, and 3 are concurrent sessions

B. 1. FOREIGN POLICY AND AFFAIRS

Location: MICHIGAN ROOM
Chairman: KENNETH J. ARROW, *Churchill College (visiting), Cambridge, England and Stanford University, Stanford, California*

- a. **An Econometric Analysis of the Effects of Foreign Aid on Economic Development: A Case Study of Greece,** IRMA ADELMAN AND HOLLIS B. CHENERY, *Agency for International Development, Washington, D. C.*
- b. **Public Goods and the Theory of Alliances,** RICHARD ZECKHAUSER, *Harvard University, Cambridge, Massachusetts*
- c. **Simulating Crisis Decision-Making,** JAMES A. ROBINSON, *Ohio State University, Columbus, Ohio*

B. 2. HEALTH

Location: MINNESOTA ROOM
Chairman: WILLIAM J. HORVATH, *The University of Michigan, Ann Arbor, Michigan*

- a. **Introductory Remarks—The Systems Approach to the National Health Problem,** WILLIAM J. HORVATH, *The University of Michigan, Ann Arbor, Michigan*
- b. **The Evolution of Operations Research in the Health Services,** CHARLES D. FLAGLE, *The Johns Hopkins University Hospital, Baltimore, Maryland*
- c. **Simulation of Hospital Systems,** ROBERT B. FETTER AND JOHN D. THOMPSON, *Yale University, New Haven, Connecticut*
- d. **Medical Records and the Appraisal of Medical Care,** KENNETH J. WILLIAMS, *St. Joseph's Hospital, Hamilton, Ontario, Canada*
- e. **Technical Problems in Areawide Planning of Hospital Facilities and Services,** HERBERT E. KLARMAN, *The Johns Hopkins University, Baltimore, Maryland*

B. 3. RESEARCH AND DEVELOPMENT

Location: IOWA ROOM

Chairman: PETER V. NORDEN, *International Business Machines Corporation, Poughkeepsie, New York*

a. **Establishing New R and D Skills,** G. J. RATH AND A. H. RUBINSTEIN, *Northwestern University, Evanston, Illinois*

b. **Quantitative Methods in New Product Planning,** B. V. DEAN, *Case Institute of Technology, Cleveland, Ohio*

c. **An Appraisal of New Approaches to R and D Management,** R. W. MILLER, *Raytheon Corporation, Lexington, Massachusetts*

d. **Some Methodological Problems in Studying the Relationship of Science and Technology to Economic Growth,** JACOB PERLMAN, *National Science Foundation, Washington, D. C.*

5:30 p.m.–7:30 p.m.

THE ELECTRONIC MIXER

Location: LINCOLN ROOM

THURSDAY MORNING, OCTOBER 8

9:00 a.m.–12:00 Noon *Session C*

1, 2, 3, and 4 are concurrent sessions

C. 1. ECONOMIC GROWTH

Location: MICHIGAN ROOM

Chairman: ROY RADNER, *University of California, Berkeley, California*

a. **Efficient Control Policies for Inter-Regional Trade,** DANIEL MCFADDEN, *University of California, Berkeley, California*

b. **Design of a Two-Sector Model of the American Economy,** EMMANUEL DRANDAKIS, *Yale University, New Haven, Connecticut,* AND PETER MIESZKOWSKI, *Yale University and the University of Chicago, Chicago, Illinois*

c. **An Algorithm for Dynamic Programming of Economic Growth,** ROY RADNER AND S. FRIEDMANN, *University of California, Berkeley, California*

C. 2. COMMUNICATIONS

Location: Minnesota Room

Chairman: Ithiel de Sola Pool, *Massachusetts Institute of Technology, Cambridge, Massachusetts*

- a. **Computer Approach to Content Analysis: Studies Using the General Inquirer System,** Philip Stone, *Harvard University, Cambridge, Massachusetts*
- b. **Language and Memory,** Victor H. Yngve, *Massachusetts Institute of Technology, Cambridge, Massachusetts*
- c. **Problems in Message Selection: On the Stubbornness of Horses,** Volney Stefflre, *Yale University, New Haven, Connecticut*
- d. **Operations Research Problems in the Dissemination of Knowledge to Underdeveloped Countries,** David G. Hays. *The RAND Corporation, Santa Monica, California*

C. 3. ORGANIZATIONAL BEHAVIOR

Location: Iowa Room

Chairman: Nate Maccoby, *Stanford University, Stanford, California*

- a. **Criteria of Organizational Effectiveness,** Stanley Seashore, *University of Michigan, Ann Arbor, Michigan*
- b. **On Organizational Effectiveness,** Joseph Berger, Bernard P. Cohen, and Morris Zelditch, Jr., *Stanford University, Stanford, California*
- c. **Organization and Role Boundaries,** L. Wesley Wager, *University of Washington, Seattle, Washington*

C. 4. TRANSPORTATION SCIENCE SECTION OF ORSA

Location: New York Room

Chairman: Richard Rothery, *General Motors Research Laboratories, Warren, Michigan*

- a. **Research in Traffic Theory in Australia,** G. F. Newell, *Brown University, Providence, Rhode Island*
- b. **A Review of the Boltzmann Approach to the Theory of Traffic Flow,** Robert L. Anderson, *General Motors Corporation, Warren, Michigan*
- c. **Traffic Flow Measurement by Sweep Sampling Air Photo Technique,** T. W. Forbes, James J. Mullin, and Miles E. Simpson, *Michigan State University, East Lansing, Michigan*
- d. **Multiple Point Experiments and Analysis in Single Lane Traffic,** Ken Crowley, *The Port of New York Authority, New York, New York*
- e. **Reducing Delays to Aircraft,** Gerold Pestalozzi, *University of California, Berkeley, California*

12:15–1:45 Twin Cities Room

LUNCHEON

Presentation: The 1964 ORSA Lanchester Prize

Speaker: David B. Hertz, *McKinsey and Company, Inc., President, TIMS*

THURSDAY AFTERNOON, OCTOBER 8

2:00 p.m.–5:00 p.m. ***Session D***

1, 2, and 3 are concurrent sessions

D. 1. TRANSPORTATION

Location: Michigan Room

Chairman: Charles J. Zwick, *The RAND Corporation, Santa Monica, California*

- a. **Simulation of MATSON's Freighter Fleet,** R. B. Farnsworth, *Matson Navigation Company, San Francisco, California*
- b. **An Approach to Transport Systems Analysis,** Siegfried M. Breuning, *National Bureau of Standards, Washington, D. C.*
- c. **Traffic Flow Theory as Applied to Transport Decision Making,** Martin Wohl, *Harvard University, Cambridge, Massachusetts*

D. 2. AGRICULTURE

Location: Minnesota Room

Chairman: Allen B. Richards, *Chemical Division of General Mills, Inc., Kankakee, Illinois*

- a. **Operations Research in Agriculture: Past, Present and Future,** C. B. Baker and G. G. Judge, *University of Illinois, Urbana, Illinois*
- b. **A Model for Predicting Outputs of Joint Product Firms in Forest Industries,** N. E. Savin, *U. S. Department of Agriculture, Washington, D. C.*
- c. **Choice of Nitrogen Application and Planning Rates for Corn: A Game Theoretic Analysis,** Earl R. Swanson, *University of Illinois, Urbana, Illinois*

D. 3. FISCAL POLICY

Location: Iowa Room

Chairman: Charles C. Holt, *University of Wisconsin, Madison, Wisconsin*

- a. **Research Applications of Quantitative Decision Analysis to Fiscal Policy—A Survey,** Erik Thorbecke, *Iowa State University, Ames, Iowa*
- b. **Problems in the Application of Econometric Models to Economic Policy in The Netherlands,** P. de Wolff, *Director, Central Planning Bureau, The Netherlands*
- c. **The Problems of Relating Operations Research to the Institutions of Government,** Roy E. Moor, *Administrative Assistant to U. S. Senator William Proxmire, Washington, D. C.*
- d. **Formula Variation of Tax Rates for Improving Economic Stability,** Albert Ando, *University of Pennsylvania* and Howard Pack, *Economic Growth Center, Yale University, New Haven, Connecticut*
- e. **Research Problems in Fiscal Policy,** *Brief panel discussion by the chairman and speakers*

5:00–6:15 TIMS College on Research and Development, Chairman, Professor Albert H. Rubenstein, The Technological Institute, Northwestern University.

5:00–6:15 TIMS College on Planning.

7:00 p.m. The Hall of States

BANQUET

Speaker: Dr. Elmer B. Staats, *Deputy Director, U.S. Bureau of Budget*

FRIDAY MORNING, OCTOBER 9

9:00 a.m.–12:00 Noon *Session E*

1, 2, and 3 are concurrent sessions

E. 1. INDIVIDUAL BEHAVIOR

Location: MICHIGAN ROOM

Chairman: GEORGE J. FEENEY, *General Electric Company, New York, New York*

a. **Stochastic Learning in Mice, Men and Machines,** MERRILL M. FLOOD, *University of Michigan, Ann Arbor, Michigan*

b. **Design and Evaluation of Probabilistic Information Processing Systems,** WARD EDWARDS, *University of Michigan, Ann Arbor, Michigan*

c. **Leadership and the Cost of Thinking,** JACOB MARSCHAK, *University of California, Los Angeles, California*

d. **On the Simulation of Group Interaction,** C. WEST CHURCHMAN, *University of California, Berkeley, California*

E. 2. SPACE

Location: MINNESOTA ROOM

Chairman: DALE E. OYSTER, *The RAND Corporation, Santa Monica, California*

a. **System Training Through Internship in the Field,** WILLIAM K. LINVILL, *Stanford University, Stanford, California*

b. **Systems Research on Space Programs at S&ID,** M. D. SCHWARTZ, *North American Aviation, Downey, California*

c. **The Art of Applying Cost/Effectiveness Analysis to Military Space Systems,** F. H. TRINKL, *Department of Defense, Washington, D. C.*

E. 3. TRADE

Location: IOWA ROOM

Chairman: ROGER R. CRANE, *Touche, Ross, Bailey and Smart, New York, New York*

a. **A Linear Programming Application in International Trade,** J. CARGILL, *Cargill, Inc., Minneapolis, Minnesota*

b. **The Design of an International Communications Network,** ROBERT FRANKLIN, *Chrysler Corporation, Detroit, Michigan*

c. **Problems and Opportunities for Marketing Science in Trade,** PATRICK ROBINSON, *Marketing Science Institute, Philadelphia, Pennsylvania*

d. **The Computer and International Marketing Management,** DAVID B. HERTZ, *McKinsey & Co., New York, New York*

12:15–1:45 TWIN CITIES ROOM

LUNCHEON

Speaker: WILLIAM G. SHEPARD, *Vice President*
University of Minnesota

FRIDAY AFTERNOON, OCTOBER 9

2:00 p.m.–5:00 p.m. ***Session F***

1, 2, and 3 are concurrent sessions

F. 1. EDUCATION

Location: MICHIGAN ROOM

Chairman: WILLIAM PLATT, *Stanford Research Institute, Menlo Park, California*

a. **A Model for International Comparison of Educational Planning,** MARY E. ROBINSON, *U. S. Office of Education, Washington, D. C.*

b. **Remote Computer Usage: Implications for Education,** THOMAS C. ROWAN, *System Development Corporation, Santa Monica, California*

c. **The Impact of New Educational Media on the Economics of Education,** PHILIP H. SORENSEN AND HENRY J. MCCUSKER, *Stanford Research Institute, Menlo Park, California*

F. 2. NATURAL RESOURCES

Location: MINNESOTA ROOM

Chairman: GIFFORD H. SYMONDS, *The Helsinki School of Economics, Finland (Visiting)*

a. **Evaluating the Consequences of Alternative Policies for Irrigation Development,** GEORGE A. PAVELIS, *U. S. Department of Agriculture, Washington, D. C.*

b. **Exploration for Natural Resources,** JOHN C. GRIFFITHS, *Pennsylvania State University, University Park, Pennsylvania*

c. **Formal Models in the Design of Water Resource Systems,** ROBERT DORFMAN, *Harvard University, Cambridge, Massachusetts*

d. **Forest Fire-Fighting Models,** WILLIAM S. JEWELL, *University of California, Berkeley, California*

F. 3. DEFENSE

Location: Iowa Room

Chairman: Edward W. Cushen, *Institute for Defense Analyses, Washington, D. C.*

- a. **Combat Vehicle Fleet Management,** Conway J. Christianson and Gerald E. Cooper, *Research Analysis Corporation, McLean, Virginia*
- b. **Aircraft Loading Considerations: A Sortie Generator for Use in Planning Military Transport Operations,** Samuel E. Eastman, *Institute for Defense Analyses, Washington, D. C.*
- c. **Methodology for the Determination of Command and Control Requirements for a Military Service System,** Raymond W. Millican, *Stanford Research Institute, Menlo Park, California*
- d. **Project PATTERN: Planning Assistance Through Technical Evaluation of Relevance Numbers,** Aaron L. Jestice, *Honeywell, Inc., Washington, D. C.*
- e. **Strengthening the Cost-Effectiveness Criterion for Major System Decisions,** Everett J. Daniels and John B. Lathrop, *Lockheed-California Company, Burbank, California*

Abstracts

A1.a. Effective Reliability for Manned Space Systems, K. A. FREDERIKSEN, *Douglas Aircraft Company, Inc.,—Missile and Space Systems Division/Space Systems Center, Reliability Assurance, 5301 Bolsa Avenue, Huntington Beach, California.*

Providing high operational reliability for manned space systems is a goal of national importance. Achievement of this goal requires a new look at reliability technology and application of operations analysis. Probably the most effective contributor to spacecraft reliability will be the crew. This effectiveness has been demonstrated on commercial transport aircraft, where extensive MIL-Spec type reliability programs have not been instituted and yet the operational reliability has been high.

There are presently several reliability considerations to explore during the design and development of manned systems. One of these involves the equipment control category. The control category differentiates between equipment which is completely automatic, completely crew-controlled, or some compromise in between. The reliability approach to these different categories is examined. How control categories are integrated through a mathematical reliability model is described, indicating how the technique of reliability apportionment, failure effects analyses, and design review are influenced by the control category. Backup control through a systematic parts/maintenance program is also developed. Some techniques for integrating the crew into the reliability picture during vehicle orbit is also considered. Providing specific crew tasks which monitor reliability progress becomes essential. Of primary importance is the data system to be used in space. In-flight data acquisition and analysis will be essential. Some possible approaches to this very important problem are developed.

A1.b. Selection of Scientific Payloads for Deep Space Exploration, JOHN C. DYER, *Avco Corporation, Research and Advanced Development Division, 201 Lowell Street, Wilmington, Massachusetts.*

Over the next decade exploration of the near earth planets will become an exciting reality. Every corner of the scientific community is clamoring for an opportunity to run experiments on these missions. Because technical and cost constraints make it possible for only a few to be chosen, we must be assured that those experiments selected will yield the maximum possible scientific information. One scientist or one discipline cannot make unbiased selections of payload. On the other hand, a mixed group of scientists will not easily agree on the "best" payloads. This paper discusses an objective, analytic selection technique which has been used on the Voyager Program to construct payload packages having the largest relative values based on diverse scientific interests.

Essentially, the technique is carried out in two steps. First, each candidate instrument is evaluated in terms of a benefit/cost index, and a merit rating is established. The second step is construction of the payload by choosing among instruments on the basis of merit rating until spacecraft capacity is exhausted. The resulting payload has maximum value within spacecraft design limits. The computational procedure is presented in simple tabular form. Some difficulties, limitations, and alternative approaches are discussed.

A1.c. Space Station Operational Availability Model with Cost Constraints, D. R. JACKSON, A. H. RAMQUIST, R. A. HOLTZ, *The Martin Company—Denver Division, Engineering Advanced Technology Department, Mail Number A-38, Denver 1, Colorado.*

Operational reliability constraints are required to define the probability of successful completion of sequential mission functions, the probability of crew safety, the probability of launch-on-time, the abort and recall capabilities, the space station resupply cycles and logistic support plans necessary to optimize space system availability and operation. The reliability dynamics resulting from complexity, mission time-usage cycle, mission environmental profile, equipment operation, and interface integration requires a simplified solution for a space systems synthesis. This paper discusses the reliability "building block" method for presentation of reliability criteria.

The method encompasses sequential mission time-phase (pre-launch, booster flight, orbit, re-entry, recovery) and space system modular (booster, re-entry vehicle, space station, ground equipment) "building blocks" and utilizes parametric reliability data as a function of time for each mission phase. This technique readily lends itself to evaluation of existing "off-the-shelf" space system modules and, when applied to conceptual space station subsystem analysis and integration, provides optimization reliability criteria for mission, size, weight, cost, and development-time constraints.

Functional models relating the "building block" concept to determination of space system optimization are presented, including mission reliability and crew safety objectives, the probability of launch-on-time, the abort and recall capabilities, and space station availability.

A1.d. The Formulation of Safety Policies for Launchings of Missiles and Space Vehicles, LEWIS A. LEAKE, *Research Analysis Corp., McLean, Virginia 22101.*

National expenditures in the missile and space fields are large and are significantly affected by the safety policies adopted by the National Ranges. Many range users have thought the safety policies too restrictive and thus too expensive.

An operations research study has permitted a fundamental review of existing and candidate range safety policies. The study involved analysis of the specific problems faced in launching ICBM's into the area of the Kwajalein Atoll. A mathematical model was derived and programmed for estimating expected casualties, probability of impact of pieces on islands, expected fraction of good missiles aborted by the safety system, and other items. A more general model involving the estimation of all national costs attributable to a safety policy was formulated.

The results of the study have already proven useful in formulating policies at the "tactical" level, and have also illustrated major weaknesses in some candidate "strategic" policies.

Decisions on what risks to accept and what to protect against in missile/space vehicle testing are some of the most difficult in the field of public safety. There is very little valid statistical data available on which to base risk estimates; many tests pose low but finite risks on non-participants (including foreign peoples); and accidents occurring from unusual, little understood causes evoke strong, even traumatic, reactions from groups. These and other factors make the problem complex.

The paper discusses the nature of the range safety problem, the approach taken in the OR study, the results obtained, and tentative conclusions to date.

A1.e. Aircraft Landing Rates for Random vs. Controlled Arrivals: A Comparison Based on Probabilities of Missed Approach, R. V. MORSE, T. W. CONNOLLY, *Control Technology, Inc., 188 Nassau Street, Princeton, N. J.*

An analysis is made through comparison of the probabilities of violating safe separation criteria on the common path for random and controlled arrivals in a terminal area air traffic control system. A statistical model is developed for computer solution of the probability of separation violation between two aircraft (requiring a wave-off or missed approach of the second aircraft) as a function of the standard deviation of the control exercised on the aircraft, the minimum separation standard, and the nominal separation between the aircraft. A common base is developed for comparing the separation violations of controlled arrivals with those which would occur if arrivals were allowed to enter the terminal area in random fashion according to a Poisson distribution. It is demonstrated that, for all arrival rates of interest, the controlled arrival case is significantly superior even if only very coarse control is exercised. It is further demonstrated, through interpretation of graphical results, that the ratio of minimum to nominal separation and the degree of control exercised must be critically specified to keep the number of separation criteria violations down to a tolerable level.

A1.f. Analysis of Sequencing and Scheduling Methods for an Automated Air Traffic Control System, M. W. HANS, A. S. JACKSON, *Control Technology, Inc., 1232 Belmont Avenue, Long Beach, California 90804.*

An automated air traffic control system requires the specification of an efficient method for sequencing and scheduling arrivals and departures at airports. This paper reviews a study which utilized a digital computer to evaluate three proposed sequencing and scheduling methods. The most efficient of these methods was recommended for implementation and comprehensive real-time simulation on the Federal Aviation Agency's experimental test-fed facility. The three methods considered are:

1) Estimated time-of-arrival (ETA) sequencing with variable time interval scheduling;
2) ETA sequencing with time-slot scheduling for arrivals and estimated-time-of-departure (ETD) sequencing with variable time interval scheduling for departures;

3) speed class sequencing with variable time interval scheduling for arrivals and ETD sequencing with variable time interval scheduling for departures.

The paper further describes the model which was computer implemented, the logics representing each of the three sequencing and scheduling methods, the Monte Carlo approach used, the effectiveness measure based upon operations rates and delays, and, finally, the results and conclusions obtained from the study.

Of the three methods considered, it is shown that speed class sequencing with variable time interval scheduling for arrivals and ETD sequencing with variable time interval scheduling for departures is the superior method.

A1.g. Target Damage Assessment: A Comparison of Two Strategies,

H. C. SEBRING, *General Electric Company—Missile and Space Division, Advanced Space Projects Department, Operations Analysis, P.O. Box 8661, Philadelphia 1, Pennsylvania.*

The complete or partial information feedback on the effectiveness of a target attack can be used to reduce the force needs to meet an attack objective. Thus, the effectiveness of one salvo can be determined and the results used to compute the second salvo requirement to achieve overall ninety percent target neutralization. The sum of the weapons used in two salvos will be less than those for a one-salvo strategy designed to meet this objective. These generalizations are applicable to any combination of ground and/or space basing for the target and launch point. The analysis in this paper considers two partial information return systems: the first, reporting merely whether minimum guidance accuracy was achieved; the second, reporting the same as the first plus weapon reliability and penetration of enemy defenses. The use of either system shows advantages over an attack with no interim damage assessment. The value of either system is dependent upon the specific probability values of weapon survival and achievement of minimum guidance accuracy. It is proved that continuous firing with the first system offers merely a minor improvement over a two-salvo strategy.

A1.h. Metri—Theory and Concept,

WILLIAM J. HUBER, *Clark, Cooper, Field & Wohl, Inc., The Pan Am Building, 200 Park Avenue, New York 17, New York.*

METRI (Military Essentiality Through Readiness Indices) is a technology to quantitatively measure and report on the readiness of military units to carry out defined missions and to provide a valid basis for decision-making in the functions of command, control, and planning. Although the technique has been developed for Navy use, the basic concepts are applicable to other services and to industry. This paper describes the basic concepts and theory of METRI.

METRI is a structured, or network, technique used to relate, quantitatively, the functional elements of a force unit. It considers personnel, equipment, and supplies, as well as measures of capability such as performance, reliability, and maintainability. The relationship between METRI and other network techniques, such as PERT and signal flow diagrams, is discussed. The mathematical models developed for treatment of personnel, reliability, etc., are also discussed.

To date, this technique has been successfully applied to the structuring of one destroyer. The model is undergoing extensive sensitivity testing and is being applied to management decision problems in the fields of inventory, maintenance, personnel, design, and budgeting.

A1.i. Metri—A Structured Approach to Management Information Systems, Danial J. Austin, *Clark, Cooper, Field & Wohl, Inc., The Pan Am Building, 200 Park Avenue, New York 17, New York.*

The underlying approach of METRI (see the Huber abstract, above) is the construction of an engineering model which represents the force unit from its assigned missions down through functional systems and subsystems, components, and items of support in a successive dependency tree structure. All elements of the force unit —men and machines—are linked together to show their proper functional relationships in performing defined tasks. The contribution of each element to its next hierarchy can be expressed numerically and can be computed in terms of its essentiality to the readiness of force units to perform various missions. The output is a readiness index on a 0% to 100% scale.

METRI is flexible, in that the model can be limited in depth and scope, to satisfy interim reporting requirements as may be significant to various levels of decision-making. It is further versatile enough to go into complete depth and detail for each individual unit or combinations of units or combination of military forces.

A1.j. Computer-Assisted Simulation of Supply and Related Systems, Jimlee R. Kemper, *Technical Operations Research—Combat Operations Research Group, Logistics Studies Field Office, P.O. Box 5175, Fort Lee, Virginia 23801.*

This simulation involves the comprehensive inclusion of the major factors associated with a logistic system. It consists of six modular components: a stochastic Monte Carlo Combat Model which provides the consumption of manpower and equipment; a Supply Model which simulates the supply activity; a Scheduled Consolidation Model; a Transportation Allocation Model which assigns an appropriate mode of transportation; a Transportation Network Model which provides the most appropriate time-distance routes for the movement of supply; and a Depot Inventory Model. The simulation is designed to accept parameter changes from players in each of the major areas outlined above. It is designed to simulate a twenty-four hour day in approximately two hours of computer time.

A1.k. A Budget Model For Procurement of Army Equipment, Charles S. Matheny, *U.S. Army—Deputy Chief of Staff for Logistics, Data Processing Center, Logistic Planning Division, Radford Terminal DDPCT-P, Radford, Virginia 24141.*

The Army budget for procurement of equipment and missiles is a major part of the total Department of Defense budget. In setting the level of this budget, the, decision-makers, by considering force requirements, assets, losses, procurement, and mobilization production, generate shopping lists which will maximize the readiness position of the force. In doing so, it utilizes such factors as production capability limitations and the consumption of the civilian economy. By employing this model and using a variety of forces and budget limitations, it is possible for the Army to compute a variety of options of readiness versus budget.

A1.l Some Uses and Limitations of Cost-Effectiveness Analysis in Military Decision-Making, William Grodowitz, *Headquarters U.S. Air Force, Directorate of Aerospace Programs, Washington 25, D. C.*

Some of the limitations of cost-effectiveness analyses, as employed by the military, are discussed. These include, for example, planning factors, strategy, technological and statistical uncertainty, as well as the complexity of costing and analytic uncertainty regarding the determination of effectiveness of multi-faceted weapons systems and forces. Some conceptual and analytic solutions to these difficulties are described. An example is provided as a vehicle by which some economic and analytic considerations, involved in military cost-effectiveness analyses, are illustrated in detail.

A1.m. Multi-Level Inventory Systems: The Case of Spare Aircraft Engines, Djoerd Hoekstra, *U.S. Army—Frankford Arsenal, Philadelphia, Pennsylvania 19137, Attention: SMUFA-3030.*

Military supply systems usually exhibit a multi-level structure, i.e., stockage points at the top of the pyramid (depots) do not directly serve equipment users but have customers which are themselves stockage points.

The objective used in "optimizing" depot level inventory control procedures for items with low demand rates (e.g., spare parts) is usually of the form: minimize the total cost of providing a specified level of service to the depot customers. The problem lies in specifying the level of service, expressed in terms of statistics such as the fraction of time in-stock or the average customer waiting time that should be given to the next lower level. It is difficult, for instance, to determine the effect on the ultimate user and the total system cost if depots maintain a higher level of inventory, thereby providing better service to their customers.

Little work has been done on the distribution of a given total inventory over different levels of stockage points in the general case. However, some systems, because of their special structure, lend themselves more readily to analysis. This paper presents the computational results obtained for a bi-level circular supply system for aircraft engine spares. It is shown that the overall system performance is very sensitive to the distribution of inventory over the two levels and that maximal system performance is obtained with a surprisingly small amount of inventory at the higher level.

A2.a. Developing a Sellout and Returns Policy for the Distribution of Newspapers. Nicholas J. Radell, *Cresap, McCormick and Paget, 100 Monroe Street, Chicago, Illinois 60603.*

The primary income source of most large metropolitan newspapers is advertising and circulation revenue. The profits due from both sources of revenue are directly related to the number of newspapers returned and sold each day. The paper will discuss the difficulties, approaches and inter-relationship involved in setting an optimum sellout and return inventory policy for a large metropolitan newspaper primary distribution channels through neighborhood newsstands and dealers. It will also reflect upon the many difficulties involved in translating a management policy into a working inventory control system.

A2.b. Balancing Accuracy and Simplicity in Determining Reorder Points, Joseph A. Hunt, *Ernst and Ernst, Union Commerce Bldg., Cleveland, Ohio 44114.*

Many methods have been developed to determine optimum reorder points in an inventory system. These methods are based on a wide range of inventory models, ranging from elementary deterministic ones to sophisticated probabilistic models with time-varying parameters. This paper deals with two topics related to reorder point calculation which were encountered while designing an inventory system for a firm in the heavy goods industry. The savings obtained by using the more complex simultaneous solution for reorder point and order quantity rather than the simpler separate solution are presented as a percent of the expected annual inventory cost. For many items these savings were not sufficient to justify the more complex procedure. Also, the effect of batch withdrawals on the order quantity is described. These withdrawals introduce another item into the total expected-cost equation—the revised equation can then be solved for the new reorder points. Both topics will emphasize the need for methods of evaluating potential savings from various levels of model sophistication.

A2.c. The Economic Sizing of Warehouses—A Comparison of Evaluation Models, C. E. Hancock *and* H. F. Kraemer, *General Mills, Inc., Minneapolis, Minnesota 55440.*

The optimum multi-product warehouse size is frequently determined from a consideration of the economic re-order quantities (EOQ) of each of the products to be serviced by the warehouse and an estimate of the minimum or safety stock. From this elementary EOQ model, an optimal solution set can be obtained; this solution, however, is shown to be only a sub-optimal set with reference to the goals of the entire corporation.

A proposed alternate, and possibly more rigorous solution, is obtained by consideration of the cash flows of the entire corporation as the objective function. Maximization of this function yields an optimal solution set characterizing the sizing of the warehouse and the optimum re-order levels. The utilization of a corporate discounted cash flow model allows for the inclusion of a dynamic characteristic in the warehouse evaluation and permits the establishment of a base for future evaluations of expansions and modifications.

In this paper, a corporate discounted cash flow model is derived which allows the evaluation of several factors which are not normally considered in an EOQ model. In particular, the cash flow model considers alternate uses for the warehouse, opportunities for outside warehousing, and alternate corporate opportunities for investment in assets other than warehouses. This model assumes that maximization of cash flow is a desired corporate goal and that treatment of expenses and fixed costs under this concept is acceptable.

A2.d. Results of Computer Simulation of Trading in May Wheat using a Triple Exponential Smoothing Model, W. SIEGEL, *P.O. Box 936, Minneapolis, Minnesota, and* A. GUGGENHEIM, *P.O. Box 328, Canoga Park, California.*

A computer simulation of trading in the May Wheat Commodity future contract was performed on price data extending from 1957 to 1964. A linear second order differential equation was fitted to the data using triple exponential smoothing. Several values of the smoothing constant were investigated. The decision rule for entering either a short or long position required that the predicted acceleration for the next day exceed a specified constant. An alternate rule using the velocity was also investigated. A comprehensive range of values of the input constants was used.

The simulated transaction was carried out on the day following the computation of the decision signal. The simulated price for buying or selling was determined by averaging the high, low and closing prices on the transaction date. Numerical results will be presented and comments on operational and statistical problems of the commodity speculator will be discussed.

A2.e. Adaptation to Production Innovation: A Model, NICHOLAS BALOFF, *Graduate School of Business, University of Chicago, Chicago 37, Illinois.*

This paper reports the empirical development of a quantitative model that may be used to predict the large, prolonged changes in manufacturing productivity that have typically accompanied the introduction of a new product or a new production process in several capital-intensive industries. It will be shown that the model provides a very efficient "explanation" or "fit" of the productivity improvement curves that have accompanied over thirty different product or process innovations in several different industries.

This research has antecedents in past studies of the "firm progress" or "learning curve" phenomenon in several labor-intensive industries. It departs from these previous findings in that the manufacturing processes considered are highly mechanized or automated, whereas learning-curve research has been largely restricted to labor-paced, manual-assembly types of manufacture. As a consequence of this different focus, the present study appears to document an essentially cognitive adaptation phenomenon. Furthermore, the results suggest a promising solution to the problem of model parameter prediction that has plagued past applications of the learning curve.

When aggregated with the findings of learning curve research, the results of this study prompt interesting speculation about the existence of a general pattern of human adaptation to task innovation that holds for many ostensibly different industrial tasks.

A2.f. An Analytical Concept for the Selection, Flow, and Transference of Technology in a Large Electronics/Aerospace Firm, ROBERT R. KLEY, *Bendix Systems Division, Bendix Corp., Ann Arbor, Michigan.*

The basic functions of any firm can be separated into 3 major classifications which are planning, control, and operations, the time span of decision being the separating variable. In the planning sector, the three basic factors of importance are the methodologies and concepts used to relate and integrate corporate Strategy, Structure, and Policies. As the physical size of a firm changes, possibly accompanied by shifts in customer and market orientation, the combinations of strategy, structure and policies change.

In the electronics/aerospace industry, these three factors readily translate into (1) a process for selecting market areas as well as developing a technological resource base for a firm, and (2) a process of ensuring that this technological activity is embedded in an environment which will permit an intra-firm flow and transference of technology. For the selection process, a method is presented which develops a technique for establishing a physical cross-sectoral relationship between the military and commercial markets using a unique tree diagram and matrix approach. A related concept for developing technological flow and transference is developed using a Shannon-Weaver Communication model. A composite organization structure model correlating all of these factors is also developed using a small group behavior, linking pin, and decision model.

This eclectic, synergistic approach is designed to achieve economies of scale through optimal use of vertical, horizontal, and circular integration in a technology oriented industry.

A2.g. Measure of Capital Investment in Professional Knowledge, J. MORLEY ENGLISH, *Dept. of Engineering, University of California, Los Angeles 24, California.*

The growth of United States enterprise has been closely coupled with capital investment. In the past, this was largely related to physical assets. However, at present the significant capital investment is in knowledge. Accounting practices fail to identify this capital and, as a consequence, a rational approach to budgeting for maintenance of such capital has been missing. It is shown how such a measure may be established. The method determines the capital investment in knowledge, both collective and individual, which benefits the firm. The nature of the depletion of this knowledge component of investment is discussed. A method for budgeting capital for maintenance and growth of knowledge capital is proposed. It is shown how this might relate to the overall capital budgeting exercise.

A2.h. Research Project Selection: Where We Stand, NORMAN R. BAKER *and* WILLIAM H. POUND, *Dept. of Industrial Engineering & Mgmt. Sciences, Northwestern University, Evanston, Illinois.*

The fields of Operations Research and Management Science have proposed solutions to some of the pressing problems of research management. In particular, within the last few years, several approaches have been suggested for structuring and solving the problems of research project selection. A review of some of these approaches suggests that except when the procedures were developed and implemented within a company or organization requiring their use, few if any of these proposed methods have been put into operation. Thus it becomes of interest to investigate the feasibility of implementing the proposed methods.

Three project selection methods of varying mathematical sophistication—ranking, economic formula, and dynamic programming—are reviewed and discussed as typical examples of what is being proposed in the literature. The main difficulties discussed are: 1) the question of the existence of the required data and the cost of collecting it, 2) the sources and effects of estimation errors, 3) the number and complexity of projects which must be evaluated, and 4) the parameters not considered. All of these difficulties place restrictions on the applicability of the methods.

Some of the implications for future Operations Research-Management Science efforts are discussed. Specifically, it is argued that the burden rests on OR-MS to demonstrate the value of these proposed methods.

A2.i. Playing the Profit Edge in Planning Research and Development Expenditures, PAUL E. WEAVER, *The Service Bureau Corporation, 425 Park Avenue, New York, N. Y. 10022.*

Recent events have indicated the need to tie-in research and development expenditures and the needs of the market place. This paper presents analytical techniques for determining the varying levels of marketing needs for each new research and development opportunity as well as an analytical model for "playing the profit edge" in selecting the most profitable research and development expenditure.

A2.j. Regression Analysis: A Tool for Costing and Budgeting, M. J. O'CALLAGHAN, *Magnetic Product Division, 3M Company, Hutchinson, Minn.*

By use of Regression Analysis it is possible to derive equations that can be used for:

1. Arriving at optimum levels of cost by alternating levels of activities within a unit, department, or the total company in cooperation with other "models" (Simulation).
2. A practical tool for economic studies (case studies).
3. A practical tool to arrive at budget estimates (long term or annual budget preparation).
4. Establishing a computed *constant cost* and supplying each incremental (or marginal) cost for the significant activities which are forecasted to occur.

In practice, the method makes use of the following basic statistical techniques:

1. Regression Analysis
   a. Least Squares Linear Regression
   b. The Doolittle method of solving multiple correlation.
2. The Control Chart

Some remarks will be made pertaining to training of accountants and their staff in this area of Applied Statistics related to accountancy.

A3.a. Personnel Assignment Decisions, WILLIAM R. KING, *Case Institute of Technology, University Circle, Cleveland 6, Ohio.*

A class of personnel assignment decision problems involving predictions of qualitative performance measures is considered in terms of the existence of optimal solutions and conceptual solvability under various conditions on the performance predictions and relative values involved. Treatment is also given to an assignment situation often appearing in the context of research management—one in which job manpower requirements are not integer valued.

A3.b. A Heuristic Approach to the Location of Multiple Facilities to Serve an Area, V. Clayton Lafferty, *Midwest R & D, United Parcel Service, 1400 South Jefferson Street, Chicago, Illinois 60607.*

Most available techniques for the location of multiple facilities to serve an area are dependent upon (a) reasonably small number of fixed points to be served to be computationally feasible or (b) a continuous function to represent the distribution of work. The computing algorithm presented searches for "locally optimum" combinations of facility locations and subdivision of the area. Any discrete distribution of expected work per unit area can be handled. The criterion of optimality used is the minimum total weighted grid distance between the unit areas and the facility to which each is assigned. The total weighted grid distance is decreased by alternately assigning unit areas to the nearest facility and moving these facilities to the centroids of work for the assigned unit areas. Ultimately both conditions are satisfied simultaneously and the facility locations are moved to a new starting position in search of a new "local optimum." The search pattern does not guarantee finding the globally optimum combination of facility locations and area subdivision. However, it is economically feasible to find enough "local optimums" to estimate the likelihood of a significantly better solution than the best solution found to date.

The algorithm is sufficiently simple that small problems (e.g. locating three facilities in an area composed of one hundred unit areas) have been hand calculated using a comptometer and slide rule. As presently programmed for the IBM 1401, up to twenty facilities may be located simultaneously. The only practical limitation on the area is the time required to compute each "local optimum."

This technique has been used to provide management with information a) indicating "good" localities in which to investigate the availability of facility sites, b) aiding in the evaluation of alternate available facility sites and c) reviewing existing facility locations and the area served by each as the work distribution changes. The application of this technique in two metropolitan areas and one complete state are discussed briefly.

A3.c. The Multifacility Production-Distribution Problem with Nonlinear Production Costs, J. Frank Sharp, *College of Engineering, Rutgers, The State University, New Brunswick, New Jersey.*

The multifacility production-distribution problem (MPDP) with linear production costs at each factory and linear transportation costs can be set up and solved as a standard linear programming transportation problem. With nonlinear production costs this becomes a nonlinear programming problem. This paper uses the Kuhn-Tucker conditions and the dual of the transportation problem in order to develop the conditions for an optimal solution to the nonlinear MPDP. For the most general case these conditions are only necessary since there may be several local optima. However, for the case of nondecreasing marginal production costs these conditions are both necessary and sufficient. Also, it is shown that for a nondegenerate optimal solution the conditions are greatly simplified. An algorithm has been developed for this problem. Other MPDP models with varying assumptions have been set up.

A3.d. Programming by Questionnaire, ALLEN S. GINSBERG AND HARRY M. MARKOWITZ, *The Rand Corporation, 1700 Main Street, Santa Monica, California.*

The authors have developed a Job Shop Simulation Program Generator (JSSPG) to illustrate the feasibility and desirability of the Program Generator approach. The present paper describes the JSSPG in particular, and considers the applicability of Program Generators in general to model building and programming.

The user of the JSSPG specifies which of 148 statements about job shop models are applicable to the particular model he wants to generate. These statements are concerned with the nature of the arrivals, routing, and process times of jobs, decision rules for job dispatch and resource selection, the existence of shift changes, absenteeism, etc. The Generator produces a job shop computer program with the desired features. The present JSSPG, intended as a test and demonstration of the Generator approach rather than as a definitive Job Shop Generator, does not include various features such as lot splitting, lap phasing and alternate routing. It can, nevertheless, generate a great variety of job shop programs, including many that have been used in practice.

Although millions of programs are obtainable by combinations of the 148 statements on the questionnaire, the work required to develop the JSSPG was more like that required to build a few large models rather than like building millions of models. This was accomplished by means of:

(a) a "program source" which includes all the commands which may be needed in the construction of any of the programs;
(b) a set of "decision tables" which specify which commands are to be included in the generated program, based on the statements selected from the questionnaire; and
(c) an "editor" which processes the questionnaire, program source, and decision tables.

The user sees only the questionnaire. The program source and decision tables are constructed once, when building a Generator for a new application area. The "program source" for JSSPG is written in the SIMSCRIPT language, which permits easy modification of the generated program in cases where the Generator can provide a model which is almost, but not quite what the user wants.

As in the job shop area, a Program Generator can be developed for any application area of wide interest which requires programs with many variations on a basic theme.

A3.e. Establishing Techniques to Determine the Quality of Business Measurements, ERNEST H. WINWURM, *Depaul University, College of Commerce, 25 East Jackson Boulevard, Chicago 4, Illinois.*

This is a follow-up of a previous paper (Quality Control of Business Measurements, presented at the meeting of the Institute of Management Sciences at Pittsburgh, Pennsylvania, March 1964) which emphasized the urgent need for a "quality control" of accounting data. In addition to strict segregation of actually measured and estimated data, the deviation of accounting data from established standards must be determined. Appropriate techniques for computing these standards as well as acceptable deviations under various conditions will have to be developed.

A survey will be made of statistical techniques which have proven themselves in other fields to examine their adaptability in the accounting area. It can be expected that a combination of established and novel procedures will be required to attain the desired results. Examples for applications on specific accounting situations will be provided to demonstrate the feasibility of the selected approach.

It is the main purpose of the paper to initiate a discussion of this all-important subject matter which has been sadly neglected by accountants until now.

A3.f. Directed Network Operating Cost and Design Criteria, R. B. McClellan, *24233 Welby Way, Canoga Park, California.*

This paper discusses the following topics as related to Directed Network; (PERT, CPM, etc.), technology: (1) The computation of directed network operating costs when specific user cost information is available. (2) Estimating the number of real activities, justified on an economic basis, in a directed network when operating cost and project-user information is known, or can be estimated. (3) Determining an ideal, envelope configuration for a given directed network when the number real activities and project dollar flow rates are known or can be approximated. (4) The general application of these criteria to the analysis of vendor supplied networks by the customer.

A3.g. The Incorporation of Step Functions and Ramp Functions Into A Linear Programming Model, B. Alva Schoomer, Jr., *Arthur D. Little Inc., Acorn Park, Cambridge 40, Mass.*

There exists a number of algorithms for solving linear programming problems in which some or all of the variables are required to have integer values. This paper describes a method for solving programming problems in which some of the variables are step functions of some other variable, as well. The method reduces the latter problem to an integer or partial integer programming problem which can be solved by existing algorithms.

A3.h. A Confidence Interval Estimate for System Availability, Harold I. Jacobson, *The Boeing Company, Seattle, Washington.*

To all realizable systems can be ascribed the characteristic of being in one of two states at each instant of time. Generally, only one of these states is considered desirable, so that the system quality can be characterized by the availability of that state. This is defined by the limit, under convergence in probability and as the duration of observation increases without bound, of the fraction of the observation time spent by the system in the desirable state. This limit will exist for most real systems. An interval estimate of state availability is obtained here. The interval estimate is exact for all sample sizes, for systems in which the durations of the two states follow exponential distributions. Where the state durations follow other distributions, the interval estimate is asymptotic with sample size, and involves the coefficient of variation of each distribution. For some distributions these coefficients have known values; for other distributions these values must be predicted. The value of the proposed interval estimate in the latter situation derives from the existence of an analysis coupling errors in values predicted for the coefficients of variation to the determination of whether the interval estimate is optimistic or pessimistic.

A3.i. Analysis of Decisions with Incomplete Knowledge of Probabilities, PETER C. FISHBURN, *Research Analysis Corp., McLean, Virginia 22101.*

This paper discusses the application of personalistic decision theory in a typical setting of decision making under uncertainty. The criterion for choice of strategy is maximization of expected utility. In this setting it is often difficult to obtain very precise measurements of the decision maker's probabilities on the states of nature and of his utilities of consequences and strategies. Here we pay particular attention to several "imprecise" measures of probability, including sets of inequalities and bounds, and see how this information may be used in trying to determine an ordering or partial ordering of the expected utilities of the alternative strategies. At the end of the paper we note how, in practice, one may try to obtain the measures of probability presented herein.

A3.j. Time Development of Stochastic Systems, HERBERT B. ROSEMAN, *Mitre Corporation, Bedford, Massachusetts.*

This paper presents an attempt to apply quantum mechanical formalism to represent the time development of stochastic systems. The results of the paper are applicable to all stochastic systems representable by discrete probability distributions and to systems described by continuous distributions whose square roots are differentiable any number of times and have all derivatives of the order of $|x|^{-N}$ (x is the random variable of the distribution) for all N.

The paper begins by defining the vector spaces necessary for proving the following theorem: The time development of the above stochastic systems can be represented by a unitary transformation of a probability state vector in the defined vector spaces. This transformation, which is induced by a unitary operator, is simply a rotation of the state vector. Next, unitary operators are defined which represent changes in stochastic systems for causes other than the passage of time. An equation for describing the time development of these operators is then derived and the paper is concluded by two examples.

A3.k. Physical Systems Analysis of Socio-Economic Situations, J. B. ELLIS, *Department of Electrical Engineering, University of Waterloo, Waterloo, Canada.*

The analysis of physical systems of any kind (e.g. electrical, mechanical, hydraulic, mixed, etc.) by a direct procedure not involving "electric network analogs" has recently become possible. The analysis of certain non-physical systems is also amenable to the powerful analytical tools and methods of general system theory, such as linear graph theory, state-space equation models, general stability and optimization theory.

The paper will contrast the new physical systems analysis procedures with existing modelling procedures, which often attempt to write down directly the solution expression to a mathematical system model, with little attempt made to exploit the properties of the component models and their interconnection. The important distinction between system variables and component parameters is shown. Examples of non-physical systems will include a state-equation model of a church congregation, and a systems model of the outdoor recreation situation in the State of Michigan. The role of standard linear programming techniques, operations research techniques, factor analysis, etc. in systems analysis is shown, along with expected range of applications and limitations of the discipline.

A3.1. Optimal Tracking of an Unknown Parameter Randomly Shifting in Gaussian Noise, MELVIN HINICH, *Graduate School of Industrial Administration, Carnegie Institute of Technology, Pittsburgh, Pennsylvania.*

This paper discusses the measurement of $r(t)$, the rate of a certain chemical process when $r(t)$ is not constant over time but shifts in a purely random manner. Assume we write $r(t) = r_i$ for $t_i \leq t < t_{i+1}$ where the t_i occur in a Poisson manner with a known rate and observe the process by means of noisy measuring instruments. Thus, $X(t) = r(t) + N(t)$ where $N(t)$ is Gaussian noise with a known covariance function. The objective is to estimate the r_i and detect the times of change in $r(t)$. This paper presents the results obtained in the case of low signal-to-noise ratio. In addition a more general theory is developed for shifting parameters in noise.

A4.a. Decisions under Uncertainty Involving Extremely Large Numbers of Possible Strategies and States of the World, MARK ALFANDARY-ALEXANDER, *Division of Operations Analysis, United States Atomic Energy Commission, Washington 25, D.C.*

In connection with decisions concerning problems of national scope, extremely large numbers of possible strategies and states of the world appear to be the rule rather than the exception. In this paper, a case is presented showing how one such problem was solved. Given boundary value and other constraints, it was possible to represent the enormous number of strategies and of states of the system by means of a continuous formulation. The values of the minimax regret solution were found to lie on the boundaries of the set of states of the system.

A4.b. A General Computer Model for Spatial Diffusion Processes, FORREST R. PITTS, *Geography Department, University of Oregon, Eugene, Oregon.*

This paper presents a general computer model for studying the process of social communication over space. The model is based upon the work of Hagerstrand at the Royal University of Lund (Sweden) and incorporates several new and flexible features. It is applicable to odd-shaped areas with barriers to communication, and incorporates an analytic solution (Omega program) to accompany the main Monte Carlo simulation program. The model is capable of predicting spatial distributions of both expanding and declining populations, and is amenable to programming the study of idea and innovation diffusion in underdeveloped areas, in areas of competing populations, and where only small amounts of communication exist between status groups, e.g., castes. A Fortran IV write-up of the model will be presented.

A4.c. Systems Evaluation of Transportation Planning Procedures, V. K. Handa and W. A. McLaughlin, *Department of Civil Engineering, University of Waterloo, Waterloo, Ontario.*

Transportation planning is assuming great importance in our national economy. Unfortunately, little is known about the complete procedure of transportation planning from the inception of need to the completion of a transportation study. Little is known about the exact quantitative effects of the decisions taken by the various parties—city councils, highway departments—involved with and responsible for a transportation plan. A systems approach should prove fruitful in determining the interrelationships of the various parties and their effects upon the overall planning process.

It is quite conceivable that the study will provide leads to decisions of a legislative and managerial nature. The study should in addition provide a more economical solution to the whole process of urban transportation planning.

A4.d. Models of Commercial Bank Decision Making, and their Interrelatedness with Monetary Policy, Edward Sussna, *Graduate School of Business, University of Pittsburgh, Pittsburgh 13, Pennsylvania.*

The research described here proceeds from two major assumptions:

1. Management science methods can be useful in solving problems of national economic policy, and,

2. Our understanding of the behavior of institutions will be improved if we disaggregate, because of the non-linear, heterogeneous behavior of the many decision units in the study.

The strategy then is to relate a series of outputs (i.e., bank decisions on loans and investments) to a number of inputs (e.g., Federal Reserve policy, relevant economic conditions, interest rate, etc.). Several different models have been developed to reflect various classes and sizes of commercial banks, and consequent differences in their environments and internal management objectives.

A4.e. Determining the Optimal Number of Volumes for a Library's Holdings, R. W. Trueswell, *University of Massachusetts, Amherst, Massachusetts.*

One of the problems that faces national progress is that of coping with the increased amount of information. It is particularly evident in the need for adequate and efficient library systems. Much work has been done in the information retrieval area but no real breakthrough has occurred. In the meantime libraries are continually increasing in size and in terms of the number of holdings in the library. The increased size leads to difficulties in using the library and to greater operating and construction costs for the library itself.

This paper is directed toward those libraries whose primary purpose is to serve the needs of the majority of its users. It must be realized that certain libraries have for their very purpose of existence the service to a very small group of special ized individuals who are looking for rare or specialized fields of information.

It is possible through sampling of current circulation to develop a criterion for defining and selecting those books that should be included in the library's holdings such that over 99 percent of the user circulation requirements can be satisfied. The technique based on last circulation date for the books in the library's holdings and in current circulation offers a relatively easy to use criterion that can be applied by non-professional library workers. Preliminary data collection at the Deering Library of Northwestern University has indicated that approximately 20–45 percent of the present holdings would satisfy 99 percent of current circulation requirements. Thus, it might be possible to reduce the holdings by a considerable amount making for ease of use and also reduce the need for expansion of the current stacks. It might also be possible through this technique to develop weeding or thinning criteria for use by librarians.

A4.f. The Diplomat, International Economist and International Businessman of the Future: His Information Environment, JOHN V. ZUCKERMAN, *Graduate School of Business Administration, University of Southern California, Los Angeles, California 90007.*

Two hundred and sixty-eight foreign service posts outside the United States are the originating points for vital information of a diplomatic-economic-commercial nature which is processed by several central stations in Washington for distribution to thirty-six government agencies and to public. Twenty million messages a year, one to thirteen pages in length pass through this system.

The system is being managed by techniques which became obsolete in 1950, when the first world-wide computer based logistics system was installed in the Defense Department. The military establishment has far outstripped our peace organizations in this respect.

What if management science were applied to this system? We will examine the information and decision-making environment of the diplomat, international economist and international businessman provided with the results of a system development program comparable to those in use in weapons system and space system operations.

A methodology is suggested to accomplish the desired result, and areas for research and future application of management science are explored.

A4.g. Management Sciences and Ethics, GEORGE R. DESI, *Westinghouse Electric, Electronics Division, Box 1897, Baltimore 3, Maryland.*

The management sciences are providing powerful tools to aid in decision-making. Ethical considerations, either as it affects decisions, or as it may be influenced by decision aids have been neglected.

Management scientists and managers must do some soul-searching to decide the extent of the manager's obligations to groups (e.g., employees, consumers, etc.) other than the organization which he serves. If, as some management writers claim, he has no other obligations, the more powerful the tools available to him, the more likely is he to become a menace to society.

With the use of large-scale computers and the "opinion surveys" of the social scientist, ethics may soon find itself an entry on a "Risk and Pay-Off" matrix!

A4.h. Nonpartisan Political Redistricting by Computer, S. W. Hess *and* J. B. Weaver, *Atlas Chemical Industries, Inc., Wilmington, Delaware and* H. J. Siegfeldt, J. N. Whelan, *and* P. A. Zitlau, *Engineering Department, E. I. du Pont de Nemours & Co., Inc., Wilmington, Delaware.*

O. R. Analysts with Delaware's Committee of 39—a nonpartisan good-government group—have solved redistricting problems for the Governor's "Committee to Study Reorganization of the Government of New Castle County."

A "warehouse-location" heuristic maps compact and contiguous districts of equal population. The minimization criterion and measure of compactness is population moment of inertia—the summed squared distances separating people from their own district's center. This method of districting has further application when legislative impasse or indifference forces federal courts to intervene.

A4.i. The Role of Mathematical Models in Education Research, Roger G. Schroeder *and* Gustave J. Rath, *Northwestern University, Evanston, Illinois.*

Current crises in education have focused the energies of management scientists on educational research. To deal with the diversity of problems in education a hierarchy of models is proposed. Three levels of modeling, the "universe", "functional", and "microscopic" levels are defined.

At the universe level, models are required to deal with a diversity of goals and institutions. At the microscopic level, many factors and difficulties in measurement are experienced. However, mathematical models can be more easily developed at the functional level. Some recent work at this level will be reviewed and several problems which might be analyzed by mathematical models will be proposed. In addition, methodologies required to open new areas will be discussed.

A4.j. Long Range Planning in Mental Health, Robert J. Hunter *and* Jerome E. Schnee, *Smith Kline & French Laboratories, 1500 Spring Garden Street, Philadelphia, Pennsylvania 19101.*

As a result of federal mental health grants-in-aid of 4.2 million dollars to support comprehensive mental health planning in the states, Pennsylvania initiated the development of a Comprehensive Mental Health Plan in mid-1963. A fundamental objective of this comprehensive plan is the development of short and long range goals for a mental health program concerned with the needs of all of the citizens of the state.

One major phase of the comprehensive plan involves the analysis of future mental health requirements and the resources which will satisfy these needs. Smith Kline and French Labs. volunteered the services of its management science personnel to assist Pennsylvania's Comprehensive Mental Health Planning Committee with some of the technical aspects of the planning process.

This paper outlines a two part study of mental health planning conducted at Smith Kline and French Labs. One part of the study focuses on Pennsylvania's 113 Outpatient Psychiatric Clinics. The second part of the study deals with the future prospects for the application of management science techniques to long range planning in mental health.

In the clinic part, data processing was performed on individual patient records to provide a data base for forecasting future outpatient clinic patient loads. A heuristic method was developed to adjust the existing clinic patient forecasts in planning the subsequent location of new clinics.

The appraisal of future trends in mental health planning revolves around the discussion of a comprehensive mental health computer model. Outlines of this model, which would represent the complex, interacting process of illness incidence and patient treatment, are presented. The potential usefulness of a comprehensive model to mental health planners is discussed along with the problems of obtaining sufficient, valid data.

A4.k. Employment Programming and Education Programming, JOHN S. MACDONALD, *United Nations, New York, New York.*

Recent techniques of projecting growth of population of working age and growth of population of school age are examined, with special attention to Western European and Soviet practice. These projections are then discussed in the light of employment-unemployment trends, the 'mix' of skills required by the economy, and educational policy. Educational programming is examined in regard to reduction of illiteracy, supply of specialized teachers, location of school plant, diversification of curricula, and coordination of vocational preparation with the level and structure of employment. Interdisciplinary mathematical techniques, model building, and cost-effectiveness analysis are already established in employment-and-education programming, but could profit by cross-fertilization with operations research.

A4.l. Solutions for Optimal Designs of Stochastic Learning Experiments, ROBERT E. DEAR, *System Development Corporation, Santa Monica, California.*

One aspect of learning experiments that is under the control of the experimenter is the choice of the sequence in which stimulus materials will be presented to subjects. This choice is frequently referred to in stochastic learning theory as the choice of a stimulus presentation strategy (in automated instruction research this is usually referred to as the choice of branching strategy). Given a mathematical model of a learning or teaching experiment and a teaching objective, one could then seek a presentation strategy which will optimally achieve this objective. Using models of learning experiments derived from one of the more prominent, current learning theories called stimulus sampling theory, we have solved for optimal Bayes stimulus presentation strategies for several different objectives. Dynamic programming procedures provide the basis for the solution for these strategies. We have been particularly concerned with computational aspects of obtaining these solutions since typically there are extensive stochastic dependencies inherent in these learning models.

B1.a. An Econometric Analysis of the Effects of Foreign Aid Upon Economic Development—A Case Study of Greece, IRMA ADELMAN *and* HOLLIS B. CHENERY, *Agency for International Development, Washington, D.C.*

The purpose of this paper is to investigate, quantitatively, the major effects of foreign aid upon the growth of a developing economy. Foreign aid plays a dual role, being both a supplement to local savings and a net addition to foreign exchange. Since the effects work themselves out throughout the economic system, a complete model is needed. One has been constructed for the Greek economy, 1951–1961; it reproduced remarkably faithfully the time paths of all endogenous variables. It can be calculated that the foreign-aid multiplier for the period was about 2.5. If the model were to continue valid until 1971, the rate of growth of the economy would slow down considerably (from 6% to 4%), and serious balance of payments problems would arise. It is concluded that an ambitious industrialization program, to substitute domestic production for imports, is needed if foreign capital imports are to be kept at reasonable levels with a growth rate between 4% and 5%.

Bl.b. Public Goods and the Theory of Alliances, RICHARD ZECKHAUSER, *Harvard University, Cambridge, Massachusetts.*

This paper treats the problem of an alliance from the standpoint of the economic concept of the public good. The paper is divided into theoretical and emprical sections; the analysis of the former being tested by the figures presented in the latter. By way of introduction, the rationale of alliances is discussed in connection with utility theory and the better known choice criteria of welfare economics. The implications of the spending of one member of an alliance for the welfare and spending of his allies are discussed in connection with indifference map analysis and the reaction curves of duopoly theory.

At this juncture the analysis turns to the effect of various decision mechanisms on the purchase of public goods. The implications of different cost sharing and voting schemes are discussed.

The conclusion of the theoretical section turns to a more measurable analysis. The expected burdens borne by each member of an alliance are related to the size of the member. It is shown that of two alliance members, one a small scale model of the other, the larger one will bear a more than proportionate share of the cost of a public good shared by the alliance.

Turning from our theoretical analysis to the statistics available for the defense spending of the NATO allies, it is shown that our hypothesis is borne out by the available data. Nations such as the United States, Great Britain, France, and West Germany spend a greater percentage of their GNP on defense, on the whole, than do small nations such as Holland, Denmark, and Luxembourg.

It is concluded that defense alliances are significant and readily analyzable examples of public goods. Some justification is given for current complaints focusing on the inadequacy of NATO forces and the inequity resulting from their finance. That is, theoretical analysis is presented to show why these problems should arise. It is felt that the available statistics bear out these contentions.

Bl.c. Simulating Crisis Decision-Making, JAMES A. ROBINSON, *Ohio State University, Columbus, Ohio.*

Crisis is defined as an occasion for decision in which an organization's goals (1) are threatened (2) by an unanticipated situation (3) requiring response within a relatively short period of time. Through modifications in Inter-Nation Simulation, experimental conditions of crisis (and non-crisis) were created. Three-hundred and thirty Navy petty officers (30 in each of 11 one-day "runs") were subjects. Crisis situations, as contrasted with non-crisis, appear to have "functional" as well as "pathological" consequences for an organization's decision-making, including its patterns of search for information and alternatives. In general, the experimental findings conform to a "satisficing" model of decision-making.

B2.a. The Systems Approach to the National Health Problem, WILLIAM J. HORVATH, *Mental Health Research Institute, University of Michigan, Ann Arbor, Michigan.*

The U. S. health system is composed of many inter-dependent parts. To enumerate some of the more obvious, there are medical practitioners, hospitals, nurses, medical technicians, pharmaceutical companies, medical research workers, medical schools, insurance companies, patients in various stages of health and wealth, and a host of governmental regulatory agencies. A modification made in any one of these components will, in time, affect the performance of all of the others. However, the degree of coupling between the parts is not sufficiently well understood to permit any reliable prediction of system-wide effects caused by disturbances originating in specific subunits.

The pressure for a better understanding of this system is increasing and stems from two sources. The tremendous increase in medical research in recent years is beginning to produce results in new medical techniques and concepts. As these new discoveries multiply, the existing system will have to be modified considerably in order to accept and utilize these innovations. Since all indications point to an acceleration of research findings, the very abundance of these may produce a deterioration of system performance unless adequate use is made of systems research to determine the effects of specific changes in the system before modifications are attempted. The second factor acting as a stimulus for the use of systems research in the health area is an economic one. The costs of health services in recent years have been sky-rocketing and this, in turn, has started a movement for greater efficiencies. A thorough cost analysis which would be a prelude to cost reduction would necessitate a complete systems evaluation.

Systems research does not provide any ready-made answers to the nation's health problems but without it no answers will be forthcoming. It is important that appropriate studies be undertaken now before the situation becomes more critical. In addition to the use of conventional techniques such as simulation, the health system should have one or more operational testing laboratories. These would be small pilot communities in which all health data would be completely documented and where the effects of new procedures, techniques and organizational changes could be studied and evaluated on a small scale before an attempt is made to modify the existing system.

B2.b. The Evolution of Operations Research in the Health Services, CHARLES D. FLAGLE, *The Johns Hopkins University Hospital, Baltimore, Maryland.*

The character of operations research in the health services has changed over the past decade very much in the way the services themselves have changed. Early studies in England and the United States places most attention on internal operating problems of the hospitals which were suffering acutely from inadequate capacity, antiquated facilities, changing labor practices and changing bases of financial support. Introspective studies such as procedures for staffing, supply and inventory problems, detailed architectural layout, and clinic scheduling and appointment procedures claimed most attention.

The solutions indicated for many of the problems have called for 1) a broadening of the base of the hospital system to include other services, such as home care, rehabilitation and longterm care, 2) an expanding of the administrative process to permit time varying allocation of resources to accommodate changeable patient needs, and 3) a development of inter-hospital relationships for administering joint problems and for planning.

During this change in the health services, research has grown in the direction of communication and decision processes. Although there will continue to be need for analysis and synthesis at operating levels, the major focus of operations research is now on problems of diagnosis and therapy and on the information systems which support these central decisions and actions.

B2.c. Simulation of Hospital Systems, ROBERT B. FETTER *and* JOHN D. THOMPSON, *Yale University, New Haven, Connecticut.*

The work reported here is an extension of previous work on the simulation of the various units of a general hospital. The basic approach is aimed at developing a set of system models which will aid hospital administrators in the design of hospital facilities and, given any design, in determining appropriate policies for operation of the facilities.

The models include a simplified version of our original maternity suite model (reported on at an earlier meeting), a model of a surgical pavilion, and a model of an outpatient facility. These models are described briefly, the experiments aimed at their validation are outlined, and results of these experiments are given as well as examples of the use of the models. In addition, considerable progress has been made in the development of a general model for predicting the operating behavior of any structure of patient organization based on care requirements as well as any staff organization allocated to serve a given patient organization. The current work of this latter phase of the project will be described.

B2.d. Medical Records and the Appraisal of Medical Care, KENNETH J. WILLIAMS, *St. Joseph's Hospital, Hamilton, Ontario, Canada.*

Keeping abreast of trends and changing patterns in the practice of medicine requires hospital medical staffs to review, analyze and evaluate their *present* practices. To determine levels of performance it is essential there be easy access to the wealth of clinical data with which hospital medical records departments are literally bulging. Traditional methods have required the busy physician to laboriously search individual medical records and actually do his own data processing.

Steeped with tradition and not exactly noted for being in the vanguard of social action the practicing physician has not welcomed the application of operations research in medical data processing as an adjunct to appraising medical care in depth. Because it is gradually being recognized that the time-honored methods of reviewing and analyzing medical care in the hospital setting so frequently result in only a perfunctory review, and because a combination of social and economic factors have brought pressure upon hospital medical staffs to more realistically audit the quality of medical care new horizons have come into view. Pioneering this field has been the non-profit, voluntary Commission of Professional and Hospital Activities with its computerized medical information systems. Even with these systems extracting from the medical records data which was previously just not accessible, there still remains the need to develop ways and means of putting this data to use. Some hospital staffs have already developed ways of utilizing this information to improve patterns of practice, but for the most part it is an untouched field.

B2.e. Technical Problems in Areawide Planning of Hospital Facilities and Services, HERBERT E. KLARMAN, *The Johns Hopkins University, Baltimore, Maryland.*

There is a widespread movement in this country toward areawide planning of hospital facilities and services. This paper discusses some technical problems facing the professional staff of a planning agency and how they are dealt with.

Included are the following problems: delineating area boundaries for study and for planning; setting the goal—planning to meet the need for services or some variant of expressed demand; choosing among requirement formulas—a bed-death ratio, present use by age and by sex, or a multivariate model; the probable influence of the supply of beds on hospital use; optimum rate of occupancy; the importance of duration of stay; the bed turnover rate as an additional measure of hospital use and as a summary of all the traditional measures; the geographic distribution of beds, including optimum size (cost of operation, cost of transportation, and range of services) and concentration of clinical material for teaching; uniform measures of physical plant—the bed as surrogate for capacity; criteria for counting beds; and indexes of obsolescence and of completed construction. The relevant literature is discussed, including the work of Airth and Newell, Bailey, the Commission of Hospital Care, Feldstein, Long, Roemer, Rorem, Sigmond, the Public Health Service, several hospital councils, and the writer. An attempt is made to indicate emerging consensus and unsolved problems.

B3.a. Establishing New R and D Skills, G. J. RATH *and* A. H. RUBENSTEIN, *Northwestern University, Evanston, Illinois.*

Data on the introduction of new R and D skills into laboratories was collected by means of 24 mailed questionnaires and 12 interviews, yielding 78 cases. Responses ranged from the establishment of a Laser Group to a Reliability Program and Pattern Recognition Research to the development of better lubricants. The first set of data consisted of estimates of time—namely: a) from the realization of the need for a skill to the overt initiation of establishment activities (T_1), e.g. first hire; b) from T_1 to full manning (T_2); c) from T_1 to adequate skill (T_3); d) from T_1 to effective out-put (T_4). It was found in the questionnaires that responses of middle and line research managers were quite useful, but that questions b and c were not operationally answerable or meaningful. Interviews were then carried out in order to expand the data base and better interpret the results from the questionnaires.

In order to adequately predict or control the establishment time, cost or quality level of a new R and D skill, many variables have to be controlled. Respondents indicated overtly or indirectly that there exist qualitative and quantitative differences between different types of R and D. For the purpose of this analysis, four categories were used—Theory, New Phenomena, Supporting Technologies, and Prime Products. Some critical variables in predicting the time and cost for establishment of R and D skills include: the State of the Art; the Source of the Requirement; the Resources Available (people, money, facilities and organizational structure); and Organizational Impact (Actual and Perceived).

The newness of the state of the art is highly correlated with the speed of establishing the R and D skills (one must decide quickly about fields which rapidly obsolesce) and the rapidity of achieving successes (in new fields obvious solutions may yield significant achievements). Another factor which greatly accelerates the establishment of new skills is customer requirements (this is especially true in Government business).

B3.b. Quantitative Methods in New Product Planning, BURTON V. DEAN, *Case Institute of Technology, Cleveland, Ohio.*

Significant research has been performed on a variety of research and development problems in such areas as evaluation, selection, scheduling, and control. However, relatively little research has been performed on the development of systems for the generation of new products and the optimization of such systems. This paper is the result of a study performed in a large consumer product company where the company's objective is to install a new product planning system. In this paper methods are developed for analyzing the flow of new product ideas, evaluation and selection of the most promising ideas, and scheduling the release of new products to meet scheduled due dates.

B3.c. An Appraisal of New Approaches to R and D Management, R. W. MILLER, *Raytheon Corporation, Lexington, Massachusetts.*

The past five years have seen rapid—and sometimes chaotic—developments in new approaches to R and D Program Management. These approaches include formal categorization of types of R and D effort, Program or Project Definition, Technical Systems Analysis, PERT/TIME and COST, Multiple-Incentive Contracting, and Configuration Management, to name some of the most well-known. While largely engendered by the Department of Defense and its agencies for the management of large-scale R and D programs, many of the principles involved apply to smaller programs, and in fact, will tend to become requirements for them in the future.

In this paper, the need for an integrated approach and understanding of these requirements is emphasized, in addition to an appraisal of proper utilization of the new approaches and criteria for their application in the R and D spectrum.

B3.d. Some Methodological Problems in Studying the Relationship of Science and Technology to Economic Growth, JACOB PERLMAN, *National Science Foundation, Washington, D. C.*

The relationship of science and technology to economic growth may be studied by any number of deductive-abstract or empirical-historical methods. In general, the former yield sharply defined and compact results. On the other hand, in spite of the mathematical exactitude of the methods in this category, the findings are often abstractions that fall short of contributing to what is already known about the causal relationship between science and technology and economic growth. In the case of the empirical-historical methods, the results may be closer to reality, but the form in which they appear are often loosely organized and of limited applicability. These difficulties are encountered whether we deal with problems on the microeconomic or macroeconomic scale.

We know that there is nothing unique about such encounters in the social sciences, but two special problems seem to stand out in studying science and technology in relation to the economy. First, the subject itself is new to economists and other social scientists, and it takes time to develop reliable methods of research. Second, the character of the subject is changing rapidly, and it is most difficult to keep pace with the dynamics of the situation.

If the progress of science and technology came to a halt, a good part of the problems would be solved. We hope, however, that such will not be the case. The other solution seems preferable; we must speed up and perfect the development of research methods so that instead of always resorting to a single rigidly defined methodology, we may be in a position to tackle the problems with multi-methodological devices.

C1.a. Efficient Control Policies for Inter-regional Trade, DANIEL MCFADDEN, *University of California, Berkeley, California.*

Many developing nations have become aware that their growth potential depends critically on the future of their export industries. This has led to the use of foreign trade controls—long a governmental policy instrument—to improve development prospects. This paper examines criteria for efficient export control policies.

A series of elementary mathematical growth models of an open economy are analyzed, using graphical techniques and simple dynamic programming. Control policies considered are import tariffs, export subsidies, trade quotas, and direct and indirect controls on investment. Particular features of some of the models are (1) neo-classical ex ante factor substitution, (2) capital rigidity, and (3) world prices with stochastic elements.

The objective of the analysis is to establish simple qualitative and quantitative criteria for establishing controls. Simplifying assumptions are added whenever necessary, and the criteria which are adaptable to available empirical data are emphasized.

C1.b. Design of a Two-Sector Model of the American Economy, EMMANUEL DRANDAKIS, *Yale University, New Haven, Connecticut, and* PETER MIESZKOWSKI, *Yale University and University of Chicago, Chicago, Illinois.*

This paper presents a two-sector model of the American economy, in which labor and capital are used to produce capital and consumption goods. Consumption not only provides some per capita "subsistence" requirements of the labor force, but also for "educational expenses" for training of labor, i.e. labor (in efficiency units) is a produced commodity. The parameters for this model are estimated from U. S. data for the post-war period.

This study (a) computes the long-term production possibilities of this model as the solution of a long-term planning problem, and (b) determines the actual paths of the model under the assumption that the propensities to spend on education and on capital goods express the U. S. consumer preferences for this period. In this version the government plays an important role. The implications of alternative types of tax finance, bond finance as against tax finance, etc., are examined in detail.

C1.c. An Algorithm for Dynamic Programming of Economic Growth, R. RADNER *and* S. FRIEDMANN, *University of California, Berkeley, California.*

An algorithm is presented for dynamic programming of economic growth in a multisector model in which (1) production of new commodities is described by differentiable production functions, (2) durable commodities disappear according to arbitrary distributions of life-length, and (3) the function to be maximized is a sum of (possibly discounted) measures of differentiable one-period welfare functions. The algorithm is based upon a method of successive approximation using an exact solution for the linear-logarithmic case. A computer program in FORTRAN is developed and the properties of the algorithm are explored in a series of numerical computations.

C2.a. A Computer Approach to Content Analysis: Studies Using the General Inquirer System, PHILIP STONE, *Harvard University, Cambridge, Massachusetts.*

The *General Inquirer* was developed in 1961 for the content analysis of written materials. An BM 7094 is used to read key-punched alphanumeric text, remove regular word suffixes, and look up words and idioms in a dictionary. The dictionary categorizes the text according to theoretical interests of the investigator. Variables considered might include expressed or assumed values, underlying types and intensities of motivation, perceived demands of the environment, and institutionalized structuring of both demands and actions. Each sentence, together with its string of descriptors found in the dictionary is stored on tape. This tape is used with various special IBM 1401 programs for counting, retrieval, and contingency analysis procedures. Applications from the fields of psychology, anthropology, survey research, business, and political science will be described.

C2.b. Language and Memory, VICTOR H. YNGVE, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

Work on the problem of programming a computer to translate from one language to another has led to new insights into the reason why human language is so complex. In writing programs to process language in a computer it has become necessary to consider how much memory space is needed to store temporary results. It would appear that most of the otherwise unexplainable complexities of sentence structure serve the definite function of making the language workable in spite of a severely restricted temporary memory. This seems to be true for all human languages although languages differ in the details of how they handle this function.

C2.c. Problems in Message Selection: On the Stubbornness of Horses, VOLNEY STEFFLRE, *Yale University, New Haven, Connecticut.*

In selection of content for advertising messages, two considerations appear of importance: (1) that a product described in this way be purchased by a satisfactory number of consumers; (2) that the product when actually seen or used not contradict the claims made about it in advertising. Techniques widely used in selection of advertising copy—derived generally from mail order advertising—do not emphasize the first or consider the second. Some alternative techniques will be discussed and examples indicating negative correlations in claims made about brands in the advertising copy and consumer judgments about brands' characters will be discussed.

C2.d. Operations Research Problems in the Dissemination of Knowledge to Underdeveloped Countries, DAVID G. HAYS, *The RAND Corporation, Santa Monica, California.*

(Abstract not available.)

C3.a. Criteria of Organizational Effectiveness, STANLEY E. SEASHORE, *Survey Research Center, University of Michigan, Ann Arbor, Michigan.*

Most organizations have many goals, not one. These goals are of different importance and their relative importance changes. Problems arise because these goals are sometimes competing, and sometimes incompatible (negatively correlated). A strategy of optimal realization of goals cannot be determined unless there exists some conception of the dimensions of performance, their relative importance, and their relationships with one another. These relationships may be one of causation, of simple correlation, of interaction; they may be linear and compensatory or non-linear and non-compensatory. A framework will be proposed for conceptualizing organizational performance, with distinctions among several different classes of performance dimensions and with consideration for several types of relationships among them. Data from sales organizations will be used to illustrate the framework.

C3.b. Stability of Organizational Status Systems, JOSEPH BERGER, BERNARD P. COHEN, *and* MORRIS ZELDITCH, JR. (*panel member*), *Department of Sociology, Stanford University, Stanford, California.*

A body of knowledge has accumulated about the influence of external status characteristics such as sex or ethnicity on the status system of formal organizations. Two properties are observed:

(1) The *diffuse* property which is a tendency for status characteristics to be

come relevant to such supposedly internal elements in the organization as its job levels, wage scales, or use of its washrooms;

(2) The *balance* property, which is a tendency for two or more relevant features of a status system to tend to come "into line" or else to generate conflict, as when women make more money than men.

The problem is to construct a model which exhibits such behavior and then to examine what other results on stability of the organization's status system can be obtained from the model.

C3.c. Organization and Role Boundaries, L. WESLEY WAGER, *Department of Sociology, University of Washington, Seattle, Washington.*

Problems associated with boundary roles and role expansion emerge from changes in institutional structure. Responses of organizational participants to role expansion are examined under varying sets of structural conditions in contrasting settings.

C4.a. Research in Traffic Theory in Australia, G. F. NEWELL, *Brown University, Providence, Rhode Island.*

(Abstract not available.)

C4.b. A Review of the Boltzmann Approach to the Theory of Traffic Flow, ROBERT L. ANDERSON, *General Motors Research Laboratories, 12 Mile and Mound Roads, Warren, Michigan.*

A review of the formalism and various implications of the Boltzmann approach to the theory of traffic flow will be presented. This approach to traffic, first formulated by I. Prigogine, involves a statistical description of multi-land traffic for which passing is allowed. The driver-vehicle population is characterized by statistical distribution functions, the most important of these being the single driver-vehicle speed distribution function. The quantitative content of the theory is based on an equation which describes the time evolution of a speed distribution function. This equation expresses, in the spirit of the fundamental Boltzmann equation of the kinetic theory of gases, the competition between the wishes of the drivers and the constraints placed on the drivers.

C4.c. Traffic Flow Measurement by Sweep Sampling Air Photo Technique, T. W. FORBES, JAMES J. MULLIN *and* MILES E. SIMPSON, *Departments of Psychology and Division of Engineering Research, Michigan State University, East Lansing, Michigan.*

In order to obtain measurements of traffic flow over a 10-mile stretch of an urban freeway during 40-minute periods of peak traffic, "sweep sampling" air photo technique was employed using a light plane and 35mm photographs at 1-second intervals. This technique has been developed by the senior author over a period of several years The photographs were measured by means of a special data reduction device punching measurements directly into cards. Corrections for slant range between air craft and highway were programmed and applied by electronic computer. Calculated from the corrected positions measurements of five vehicles in each lane (sampled over 5 seconds) were velocity, time and distance headways (rear bumper to rear bumper) and traffic volume estimates. From these quantities, distributions, variances and means were calculated for the final analysis. Examples of distributions and estimates obtained will be given.

The research was supported by a contract with the United States Department of Commerce, Bureau of Public Roads.

C4.d. Multiple Point Experimentation and Analysis in Single Lane Traffic, Kenneth W. Crowley, *The Port of New York Authority, 111 Eighth Avenue, New York, New York.*

Samples of vehicle headway times and velocities have been collected simultaneously at up to six points in a lane of the Holland Tunnel. Spatial densities and travel times have been calculated for the inter-point segments. Analyses have been made of point and segment vehicular characteristics with particular attention given to those which appear to act as prior indicators, either in space or time, of congestion. Finally, these findings will be discussed in terms of their utility in altering and improving the existing Tunnel Traffic Flow Control System.

C4.e. Reducing Delays to Aircraft, Gerold Pestalozzi, *University of California, Berkeley, California.*

A significant part of the delay experienced by aircraft, particularly under instrument flight rule conditions derives from the necessity to funnel all aircraft landing at an airport through a common final approach. The new air traffic monitoring and control techniques under development by the FAA will make it technically feasible to alter the present "first come-first serve" rule for feeding aircraft into the final approach. This paper studies a number of alternative rules, e.g., assigning priorities to aircraft of different performance classes, in order to find reductions in average delay per aircraft, average delay per passenger, or probability of long waits. The effect of different rules on the possibility of interposing departures between landings is also discussed.

D1.a. Simulation of Matson's Freighter Fleet, R. B. Farnsworth, *Matson Navigation Company, San Francisco, California.*

Matson research has been solving freighter fleet system problems for the past five years using simulation techniques. This paper draws on that experience to present guidelines for general use of simulation in solving systems problems. The common context of the several simulation examples used in the paper is set out with a description of the Hawaiian transportation problem. This description highlights some of the decision areas that require a system approach. The design and implementation of a large-scale model of the Hawaiian service is presented as a specific example. An analysis of this development effort and its appication demonstrates the general guides evolved by the group for using simulation techniques. Present effort utilizing simulation is reported as a case study in applying these guides. Results are compared to other published works on simulation to reinforce the guides that Matson research has developed.

D1.b. An Approach to Transport Systems Analysis,

SIEGFRIED M. BREUNING, *National Bureau of Standards, Washington, D. C.*

This paper discusses the application of systems analysis techniques to large scale transporation problems. The complexities of comprehensive transportation problems are described and the factors involved defined and analyzed. The significance of each factor in the combination of them into logical sets of solutions are outlined and their characteristics with respect to the real system discussed. Methodology for the solution of these problems is described when its exists. Needs for new methodology are also outlined on the basis of this study. The work is based on a conceptual approach to real example problems which are then abstracted to the general case where possible. The purpose of the study is to achieve a better understanding of the complexity and interrelationship of transportation.

D1.c. Traffic Flow Theory as Applied to Transport Decision Making,

MARTIN WOHL, *Director of Research, Transport Research Program, Harvard Graduate School of Public Administration, Cambridge, Massachusetts.*

The development of traffic flow theory has proceeded at a healthy pace for some two or three decades, has absorbed the interest and talent of many researchers, and has resulted in the presentation of a rather formidable body of literature. These events alone suggest that it is appropriate to review this effort, and to assess its relevance, balance, and direction. Such a review when placed along side a more general and comprehensive framework, for transport decision making, and when considered in light of the overall technical requirements, should permit a more valid and current criticism of traffic flow theory research, and thus lead to more reasonable conclusions regarding its potential and make-up.

D2.a. Operations Research in Agriculture: Past, Present and Future,

C. B. BAKER *and* G. G. JUDGE, *Department of Agriculture Economics, University of Illinois, Urbana, Illinois.*

Operations Research methods are defined, described and related to quantitative research methods in general that are used in agriculture. The decision or question frame of reference that directs quantitative research in agriculture is discussed. The various structural elements of agriculture are defined with particular reference to their economic properties and requirements. Both organizational and operational characteristics are referred to, although, in keeping with the theme of the program some emphasis is placed on operational characteristics of agricultural units.

Information required for decision making in the various agricultural units is specified. Special attention is directed to the "how much" character of informational requirements, if the consequences of alternate courses of action are to be reflected operationally. Also the influence of Operations Research methods on research questions asked will be noted.

Examples will be developed of contributions made by Operations Research methods to improve information available for decision making in agriculture and, where relevant, to methodology. Finally, problems of data and conceptual requirements that have yet to be met are outlined. Some comments are suggested to close these "empty information boxes," especially the needs for methodological development.

D2.b. A Model for Predicting Outputs of Joint Product Firms in Forest Industries, N. E. SAVIN, *Pacific Southwest Forest and Range Experiment Station, United States Forest Service, Post Office Box 245, Berkeley, California 94701.*

The paper treats the general problem of predicting the vector of outputs of a joint product firm for given vectors of inputs and output prices. The problem of how to reduce the error in output prediction due to nonhomogeneous inputs is examined in detail. An econometric model of the output expansion path as a function of the input vectors is derived from a stochastic theory of the joint product firm. The theory assumes two sources of random variation: input quality and technical efficiency. A procedure for defining homogeneous input classes is suggested. The procedure makes use of the technique of multivariate regression (where the dependent variable is a vector of jointly dependent random variables).

U. S. Forest Service appraisal of standing timber to be sold to sawmills is one example of the general problem. A sawmill is a joint product firm which uses nonhomogeneous inputs and which is subject to variation in technical efficiency. On the basis of sample data collected at average mills the parameters of the output expansion path model are estimated including the standard error of forecast matrix. The multivariate regression technique is used to define standing timber grades which reduce the "size" of the standard error of forecast matrix. The computations are carried out on the IBM 7090 using a recently written stepwise multivariate regression program.

An economic decision problem of the firm is to choose the optimal (profit maximizing) output expansion path for alternative vectors of output prices. The proposed output expansion path model, and the associated multivariate regression technique for defining homogeneous inputs, are tools which the firm can use to solve this problem.

D2.c. Choice of Nitrogen Application and Planting Rates for Corn: A Game Theoretic Analysis, EARL R. SWANSON, *Department of Agricultural Economics, University of Illinois, Urbana, Illinois.*

Commercial forms of nitrogen fertilizer are an important input in corn production. In addition to a number of other factors, the optimum economic amount to apply is conditioned by the planting rate per acre and the available soil moisture. An experiment conducted on Flanagan silt loam (a highly productive, well drained soil) provides a production function with corn yield as the dependent variable, and with nitrogen fertilizer, planting rate, and available soil moisture as the independent variables.

Information is available on the current available soil moisture at the time of planting corn. By use of a procedure developed by van Bavel this initial available soil moisture, together with subsequent precipitation and evapotranspiration data, can be used to estimate the available soil moisture during a 17-day critical period in corn growth.

The actions assumed to be open to the producer at planting time are 12 combinations of levels of nitrogen fertilizer application and planting rates. The consequences depend (in the absence of irrigation) on weather circumstances beyond the control of the producer. For each of several available soil moisture levels at planting time, ten seasons are constructed, based on actual historical precipitation and evapotranspiration data. These constructed seasons are treated as strategies available to Nature in a zero-sum two-person game. The solutions of various forms of the game theory model are compared.

D3.a. Research Applications of Quantitative Decision Analysis to Fiscal Policy—A Survey, ERIK THORBECKE, *Iowa State University, Ames, Iowa.*

A small amount of pioneering work in this area has been done mostly in other countries, and it has received relatively little attention here. The purpose of this paper is to summarize and evaluate research that has been done on the application of quantitative decision analyses to fiscal policy problems.

D3.b. Problems in the Application of Econometric Models to Economic Policy in The Netherlands, P. DE WOLFF, *Central Planning Bureau, The Netherlands.*

The approach which the Dutch have taken to their economic policy problems in the postwar period will be surveyed briefly. Then recent policy problems in The Netherlands will be examined, and using an econometric model various alternative approaches will be explored for reaching acceptable solutions.

D3.c. The Problems of Relating Operations Research to the Institutions of Government, ROY E. MOOR, *Administrative Assistant to William Proxmire, United States Senate, Washington, D. C.*

Operations Research has become an extremely valuable area of science because it has combined techniques from economics, statistics, mathematics, and several of the natural sciences in order to answer certain types of immediate policy questions. Primarily, these techniques have been used as a managerial tool aimed at the solution of problems of optimization.

Optimization questions exist in the public policy areas, as well as in the field of business and military decisions. Operations Research can be an extremely useful tool for the government both in the executive and legislative branches. However, in order to make effective use of this tool, the unique institutional framework within which government decision-making occurs must be taken into account. The implications for Operations Research of these institutional characteristics, such as timing lags, difficulty of optimization goals, and restrictions on freedom of action, will be discussed in this paper.

D3.d. Formula Variation of Tax Rates for Improving Economic Stability, ALBERT ANDO, *University of Pennsylvania, Philadelphia, Pennsylvania, and* HOWARD PACK, *Economic Growth Center, Yale University, New Haven, Connecticut.*

Simulation studies of an econometric model have been made to explore the possibilities of offsetting fluctuations in price level and unemployment through countercyclical changes in tax rates governed by a Phillips type control formula.

D3.e. Research Problems in Fiscal Policy—a brief panel discussion by the chairman and speakers.

E1.a. Stochastic Learning in Mice, Men, and Machines, MERRILL M. FLOOD, *University of Michigan, Ann Arbor, Michigan.*

This paper discussed the use of stochastic behavioral models to describe the observed sequences of responses by several kinds of subjects during experiments in which the subject responds sequentially with one from among a few possible acts, with each response followed immediately by either an apparently favorable or apparently unfavorable outcome. The parameters of the "Symmetry Model" used remained reasonably invariant in working with rats when experimental conditions were changed in a variety of ways, yielding good "scope" for the model, and the parameters for rats differed greatly from those for human subjects—with much greater differences also between human subjects than were found among rats of one genetic strain. The Symmetry Model was also used to construct a computer code for numerical analysis that selects among several possible iterative algorithms frequently during the course of one calculation, adapting on the basis of the outcomes of successive steps. Similar uses were made of the Symmetry Model to explain and predict task-performance in small groups, and in the design of an adaptive sequential information dissemination system, and the paper includes a preliminary report on these applications.

E1.b. The Design and Evaluation of Probabilistic Information Processing Systems, WARD EDWARDS, *University of Michigan, Ann Arbor, Michigan.*

A major task of a command and control system often is to determine what is happening in its environment. Conclusive information is usually lacking, so such systems must attempt to synthesize thousands of items of information, each individually worth little, into an accurate picture or diagnosis of the relevant environment. Current systems (e.g., the NORAD Combat Operations Center) use sophisticated display and information retrieval devices, but leave the task of synthesis followed by decision to unaided human judgment. The ideas of Bayesian statistics offer the basis for a new technology of diagnostic information processing. In the Bayesian view, probabilities are orderly or consistent opinions, and Bayes' theorem of probability theory is the optimal rule for how opinions should be revised on the basis of information. The crucial input to Bayes' theorem is the probability, for each datum to be processed and for each hypothesis of interest, that the datum would occur, if the hypothesis were true. Research suggests that experts can estimate such probabilities, or numbers which can be translated into them, with fair accuracy. Once such probabilities are available, a desk calculator or computer can easily synthesize them into a posterior distribution that gives the current probability of each hypothesis of interest on the basis of all the available data.

Details of the design of such a Probabilistic Information Processing System (PIP) are presented. Laboratory research completed and in progress is reviewed, along with simulation studies intended to compare PIPs with traditional information processing systems in complex and realistic environments.

E1.c. Leadership and the Cost of Thinking, JACOB MARSCHAK, *University of California, Los Angeles, California.*

What is the *rationale* of "hierarchy" and, in particular, of any "chain of command" and, therefore, of "leadership?" Since there is, in general, a one-to-many correspondence between commands and the commander's information, a chain of command implies loss of information. Hence, if the expected payoff (whether a scalar or a vector) were considered without allowing for organizational cost (the cost of information and of decision-making) and for errors and delays, the command principle would be, in general, inefficient compared, for example, with some arrangements in parallel instead of in series. The command principle may be efficient and indeed preferable to other arrangements if organizational costs, errors, and delays are taken into account; provided the available pool of decision makers is such as to make specialized decision making advantageous. This includes a leader's specialization in "meta-decisions," i.e., the activity of "organizing" (or "re-organizing").

E1.d. On the Simulation of Group Interaction, C. WEST CHURCHMAN, *University of California, Berkeley, California.*

The paper describes the results of over thirty experiments in task-oriented group experiments designed to test methods of implementing OR recommendations. On the basis of these experiments, it has been possible to classify the communications between the subjects.

This classification becomes the basis for simulating group behavior. The simulation can then be designed to serve as the environment for a single subject, with a consequent saving of cost and time in replication, and increased control. The whole method is one proposed solution of the problem of experimental control in large group experiments.

E2.a. System Training Through Internship in the Field, W. K. LINVILL, *Stanford University, Stanford, California.*

The area of system design requires new theoretical breadth and poses new problems for the engineering school. While breadth in mathematics and in physical and behavioral sciences is essential, this theoretical background must be tied down by interaction with real world problems. Such problems are provided the students by the equivalent of laboratory or clinical experience. Stanford has a program of internship with industry to provide such interaction; specific field problems will be presented and discussed.

E2.b. Systems Research on Space Programs at S&ID, M. D. SCHWARTZ, *North American Aviation, Downey, California.*

In the pursuit of national space goals, a major task of the National Aeronautics and Space Administration is planning and programming for manned exploration of space. The principal role of industry is to work with NASA to convert these plans and programs into operational systems.

From several points of view, this is a problem in allocation of resources. In its larger aspects, the problem is necessarily constrained by the need for economy in dollars, scientific manpower, and industry-wide engineering capability to meet a challenging time schedule. At the other extreme, it requires hard choices among preferred technical/operational alternatives at the subsystem and system component levels. This is an environment in which the scientist, the systems and operations analyst, and the management expert can make significant contributions, since the methodologies of these disciplines can provide the pattern for adjusting to the technical/operational alternatives within the resource constraints.

E2.c. The Art of Applying Cost/Effectiveness Analysis to Military Space Systems, F. H. TRINKL, *Department of Defense, Washington, D. C.*

Often arguments are made that cost/effectiveness analysis cannot be applied to the planning of the development and operation of military space systems because of the many uncertainties. Factors such as mission effectiveness are asserted to be non-quantifiable even though agreement can be obtained on such uncertainties as performance, availability and cost.

Decisions regarding the selection of alternative military space systems obviously have to be based on judgments as to the effectiveness of these systems in performing missions which on the national level are considered important. Cost/effectiveness analysis can contribute toward improving these judgments by indicating preferred courses of action. This paper will be concerned with conceptual tools for improving analyses of alternative space efforts.

E3.a. A Linear Programming Application in International Trade, J. CARGILL, *Cargill, Incorporated, Minneapolis, Minnesota, and* D. H. SCHILLER, *Peat, Marwick, Caywood, Schiller and Company, Chicago, Illinois.*

Some observations on the Art of Identifying situations wherein the techniques of Linear Programming can be employed. The case in point consists of a large scale trade of an esoteric commodity to a foreign nation; how the opportunity was identified, and how it was organized to take advantage of Operations Research Techniques, and the outcome. In short, the Diary of an Opportunity.

E3.b. The Design of an International Communications Network, ROBERT FRANKLIN, *Chrysler Corporation, Detroit, Michigan.*

(Abstract not available.)

E3.c. Problems and Opportunities for Marketing Science in Trade, PATRICK ROBINSON, *Marketing Science Institute, Philadelphia, Pennsylvania.*

The Marketing Science Institute is engaged in comparative marketing systems studies contrasting U.S. experience with the characteristics and the growth patterns of marketing in selected nations at varying stages of socio-economic development. The Institute recently completed a study of companies in the European Common Market which indicates the opportunities for, and accelerated acceptance of, modern computational and operational model building techniques in European business. MSI is also investigating the feasibility and utility of an international marketing and trade information center suitable for the storage and processing of information needed for research by industry, government and universities engaged in international trade and education.

E3.d. The Computer and International Marketing Management, David B. Hertz, *McKinsey & Co., New York, New York.*

In the past, international marketing has been well served by traditional marketing concepts and techniques; however, there are new challenges arising from changes in living standards and marketing competition. The need to pare costs and deal with new roles and changing conditions have caused managers to seek new and improved tools. The computer and associated communications equipment comprise one of these important new tools. Other users have already applied data processing to the development of better information in many key areas. This paper covers applications to international marketing of these information processing concepts.

F1.a. Model for International Comparison of Educational Planning, Mary E. Robinson, *U. S. Office of Education, Washington, D. C.*

Four major areas of comparisons are selected as of utmost importance in revealing the likenesses and differences in the educational planning of various countries:

1. The identification of political and bureaucratic, lay and professional groups involved in educational planning, channels used to get consensus on estimates of educational needs, and to convert judgments of experts to nationally accepted goals.
2. The identification and specification of the number and nature of the overall educational goals—purposes the society expects education to contribute to or to achieve (i.e., the production of required manpower skills and abilities, citizenship skills and abilities, production of new knowledge through research, etc.).
3. The identification and specification of implementing goals (i.e., educational factors which in the continuum of educational planning must be considered as objectives in themselves). Implementing goals include qualitative and quantitative targets for students enrolled, teachers, curricula, methods-media-materials, ancillary services, facilities, and equipment, organization and administration, and funding.
4. The content of the resulting plan—a schedule of time-phased targets and units of work constituting priorities linking attainment of implementing goals (enrollments, teachers, expenditures) to the attainment of overall goals (manpower, citizenship skills, et al.).

When a country's overall educational goals are placed on the vertical axis of a matrix, and the implementing goals are placed along the horizontal, the resulting intersect areas may be used to indicate qualitative and quantitative data and descriptive and evaluative research findings that bear on the nature and magnitudes of educational effort devoted to particular problems indicated by the intersect (i.e., the estimation of teacher requirements or teacher training facilities needed to support manpower training objectives). Use of this matrix in the analysis of the Swedish, Dutch, British, and some aspects of U. S. educational planning will be cited.

F1.b. Remote Computer Usage: Implications for Education, Thomas C. Rowan, *Systems Development Corporation, Santa Monica, California.*

Experimental operation of computers by multiple users located remotely is being extended with increasing momentum into a variety of fields. Problems with equipment, computer programs, and other system elements are being examined, and preliminary solutions are being tested and evaluated. This paper briefly reviews these developments and discusses the following and several other important implications for education: the impact on classroom procedures, curriculum design, and programmed instruction; the consequent centralization of administrative support and effects on local autonomy; the resulting acceleration in the introduction of computers in technical education at the university, college, and secondary-school level.

F1.c. Impact of New Educational Media on the Economics of Education Philip H. Sorensen *and* Henry J. McCusker, *Stanford Research Institute, Menlo Park, California.*

The educational system must cope continuously with conflicting goals of quality-for-many and least-cost. The educational enterprise is labor-intensive but quality labor is in short supply, expensive, and historically unspecialized. Developments in instructional technology, curriculum design, and staff organization suggest some radical, but plausible, re-allocations of scarce resources within budget constraints. Some alternatives for a K-12 public school system were considered analytically under conditions where some system characteristics were held constant (i.e., total budget, budget allocated to instruction, number of pupils) and other characteristics were varied (i.e., average salaries of professional and sub-professional personnel, ratio of professional to sub-professional personnel, instructional budget allocated to salaries). Within these limits, the most radical re-allocation that appeared "reasonable" showed (1) 48% increase in average salaries, (2) 30% increase in funds for instructional materials, (3) 75% increase in the number of sub-professionals per professional staff, and (4) 46% decrease in total staff. This decrease in staff size increased the number of students per total instructional staff, but the increased student:staff ratio was compensated for, in part, by greater use of instructional technology and, even so, remained below 33:1.

F2.a. Evaluating the Consequences of Alternative Policies for Irrigation Development, George A. Pavelis, *U. S. Department of Agriculture, Washington, D. C.*

A preliminary purpose of this paper is to present a rational method for projecting the acreage of land irrigated in separate river basins of the United States, as conditioned by: (1) Four major hypotheses of the absolute and relative importance of additional Federal versus non-Federal irrigation; (2) approximations of the maximum irrigation feasible as based on regional variations in available water supplies; and (3) historical rates (1939–59) of irrigation development as estimated from the Census of Agriculture. The end purpose is to show how the above results can be used to quantify regional variations in the sensitivity of irrigation to various policies for additional Federal and non-Federal development that might be postulated and/or recommended. While, at this stage of the study, there is no direct emphasis on optimizing regional rates of irrigation development, the procedure makes it possible to identify continuing rates of development consistent with acreages that have been calculated in other studies as being optimal for discrete points in time; i.e., 1975, 1980, etc.

F2.b. Exploration For Natural Resources, JOHN C. GRIFFITHS, *Pennsylvania State University, University Park, Pennsylvania.*

The objective of exploration for natural resources should be to compile an inventory of the potential resources of some defined area. Generally this is accomplished in a piecemeal fashion by searching for different targets, by different means, at different times. This seems an inefficient procedure as may be shown by comparison of success ratios with and without "technical advice."

The distributions of specific kinds of natural resources are not random but clustered. Initially, however, with maximum uncertainty about outcome, there is no choice but to treat the distribution of prizes of all kinds as equally likely everywhere. Based on the results of this grid (area) sampling, those areas of greatest potential may then be selected for increased effort. The exploration program may therefore be represented as a sampling design with increasingly restricted stratification of the initial population based on increasing knowledge about outcome. Such a program may be simulated by means of the "Engel Model" and the results from different initial distributions, and different investment levels, upon successful outcomes may be simply demonstrated.

F2.c. Formal Models in the Design of Water Resource Systems, ROBERT DORFMAN, *Harvard University, Cambridge, Massachusetts.*

(Abstract not available.)

F2.d. Forest Fire-Fighting Models, WILLIAM S. JEWELL, *University of California, Berkeley, California*

Forest and wildland fires are one of man's greatest wastes of natural resources, destroying watershed, grazing, and recreational values, as well as timber and man made property. Furthermore, the methods of fire fighting are such that proper organization of manpower and equipment is the most efficient way of reducing forest fire waste, short of some radical technological breakthrough. Several models of fire-fighting organization will be examined from an analytic point of view, including: size of initial attack, dynamic reinforcement tactics, search and distribution strategies, manpower standby planning, and optimal location of suppression equipment. Basic planning principles will be emphasized, concluding with a discussion of unsolved problems.

F3.a. Combat Vehicle Fleet Management, CONWAY J. CHRISTIANSON AND GERALD E. COOPER, *Research Analysis Corporation, McLean, Virginia.*

The Research Analysis Corporation has recently concluded perhaps one of the most comprehensive operating and maintenance support analyses ever undertaken on any piece of Army equipment. A history was kept on 600 individual tanks from the day issued. The records cover 2½ years of tank use with accumulated miles, in some instances exceeding 5000.

The prime purpose of the study was to establish the life expectancy for the tank, considering cost, reliability, and obsolescence. Management now has a greater capability for measuring fleet wearout, determining fleet replacements (procurement requirements), and assessing combat readiness. Other by-products are: repair capacity required to support a given fleet size, maintenance budget requirements, etc.

F3.b. Aircraft Loading Considerations: A Sortie Generator for Use in Planning Military Transport Operations, SAMUEL E. EASTMAN, *Institute for Defense Analyses, 1666 Connecticut Avenue N.W., Washington, D. C.*

The purpose of this paper is to describe and evaluate a new technique (called a Sortie Generator) for estimating the number of sorties required for the performance of military air transport missions, and to present loading factors for selected aircraft types and deployment cargoes obtained by application of the method. Aircraft loading considerations deal with details regarding the nature of the cargo and passengers to be transported, the dimensions and available weight-to-space relationship of the lifting vehicles, and the myriad of "ground rules" that must be followed in loading.

A digital computer model of aircraft loading was designed, programmed, and, to a limited extent, tested. The model is applicable to planning transport aircraft operations, comparison of different aircraft types, and for study of alternate cargo compartment configurations.

F3.c. Methodology for the Determination of Command and Control Requirements for a Military Service System, RAYMOND W. MILLICAN *Stanford Research Institute, Menlo Park, California.*

Stanford Research Institute's continuing command and control research has developed a methodology for determining command and control requirements of systems at the national level. First, alternative strategic concepts and threats are postulated. Second, a prediction is made of the significant activities and missions which will involve the system in the environment to be studied. Next, the decisions and necessary supporting staff estimates or analyses which will be made within the system are identified. The estimates or analyses lead to information requirements. Summation of information requirements permits description and quantification of the data base. Data sources and needlines are identified and data flow is described. The study develops the foregoing methodology by describing its application to the Department of the Army Command and Control System.

F3.d. Project PATTERN: Planning Assistance Through Technical Evaluation of Relevance Numbers, AARON L. JESTICE, *Military and Space Sciences Department, Honeywell, Inc., Washington, D. C.*

Project PATTERN is a continuing, large-scale, corporate effort to assign quantitative, relative values to the importance of conducting *R* and *D* on the various technology deficiencies which now stand in the way of the achievement of the national security objectives for the decade from 1968 to 1978. The entire spectrum of technology deficiencies and subjective probability techniques with mission and state-of-the-art forecasts. The ranked emphasis the nation should place on a given program or technology is evaluated in terms of (1) *Relevance*—which measures the importance to the national objective of solving a given deficiency; (2) *Status, Timing*—which measures the industry's capability to solve the identified technical problem; and (3) *Cross Support*—which measures the degree of technical growth payoff that will result from the solution of any specific problem. In this process all military-oriented government tasks are evaluated without regard to specific characteristics or objectives of the company. The company R and D projects are then read-out and ordered through the use of such density functions as funding types, capability, and competition depending on the level and scope of inquiry of the specific individual. The data are subjected to sensitivity analyses and nonparametric statistical inference tests to establish a confidence interval on the outputs. The paper describes the method of reducing the necessarily complex data to numerical form and of reaching analytical solutions of representative questions facing management in corporate R and D planning.

F3.e. Strengthening the Cost-Effectiveness Criterion for Major System Decisions, EVERETT J. DANIELS AND JOHN B. LATHROP, *Lockheed-California Company, Burbank, California.*

Cost-effectiveness as a criterion guiding decisions concerning development and procurement of major defense and space systems is under heavy attack. It is alleged that it fails adequately to take into account intangible but important factors—threat uncertainty, the lessons of military experience, the value of flexibility, national prestige, political feasibility, scientific objectives, etc. Some feel that a need for cost-effectiveness demonstration of every new system, using current rules, will effectively prevent the development of new systems. Yet cost-effectiveness as a criterion must survive because it can recognize objectives and logically permit the most economic allocation of scarce resources in reaching those objectives.

While defending the principle of cost-effectiveness, this paper suggests that its methodology is incomplete as currently applied and proposes some approaches to its improvement. These include provision for measurement of the vulnerability of decisions—or of lack of decision—to uncertainty in premises. This feature, as well as answers to many of the objections raised by cost-effectiveness' opponents, can be included by suitable modification and expansion of criterion functions. Such modifications are suggested, involving introduction of quantified expert opinion. This type of quantification has proved useful in studies of methods for assisting in system design and resource allocation decisions.

Society Affairs

CALIFORNIA STUDENT SECTION (BERKELEY)

(*The following report, prepared by* RICHARD J. SWERSEY, *President of the Student Group, was submitted in letter form to* GORDON SHELLARD, *ORSA Retiring Secretary. The material below has been abstracted from that letter.* Editor.)

The Chapter activities can be broken down into four main categories:

1. Regular monthly meetings. At each meeting we attempt to have discussions of subjects other than those taught in our courses. If possible, we try to get a speaker from industry. At other times we invite members of the faculty or graduate students to describe some interesting aspect of their own research. The speakers and their topics for the past year are as follows: (a) BENNETT FOX, Graduate Student in Industrial Engineering—"Scheduling of Admissions Into Hospitals". (b) HEINER MUELLER-MERBACH, NATO Fellow in Operations Research—"New Solution Methods For The Transportation Problem". (c) RICHARD J. SWERSEY, Graduate Student in Industrial Engineering—"Mineral Exploration—A Bilinear Programming Problem". (d) EDMUND EISENBERG, Assistant Professor of Industrial and Electrical Engineering—"A Class of Zero-One Problems". (c) ELMER DOUGHERTY, Senior Staff Mathematician, Standard Oil Co., of California—"Problems of Implementation of Operations Research in an Industrial Organization". (f) MERRILL T. FLOOD, Visiting Professor of Business Administration—"Optimization Through Iterative Search Techniques". (g) ROY RADNER, Professor of Economics and Statistics—"Command and Control Decision Rules Based on Failure—Restoration Processes". (h) RICHARD W. COTTLE, Graduate Student in Mathematics—"A Convex Programming Algorithm".

2. Joint Seminars in Operations Research with Stanford University. At our request the first such seminar was arranged at Stanford and was held on April 25. Students and faculty found the exchange of ideas stimulating and both groups were enthusiastic about continuing these meetings. The speakers were PROF. WILLIAM S. JEWELL, University of California, "Divisible Activities in Critical Path Analysis" and PROF. ROY D. LAVE, Stanford University, "Markov Models in Quality Control". A mixer was held following the papers. We have scheduled the next joint seminar at Berkeley for October 1964; the papers at this meeting will be presented by graduate students from both schools. It is our hope that once these meetings become a regular event, they can be organized as studies in depth of a particular phase of Operations Research.

3. Social functions. We feel that the ORSA chapter should provide some social program for its student members, who are of diverse backgrounds and interests. In this way we hope to promote social as well as professional friendships.

4. *International library.* The student section is proud to have been chosen the custodian of an international library of Operations Research materials. We have the full cooperation and support of Dr. George B. Dantzig, Chairman of the Operations Research Center and of the staff of the Center in pursuing this project; we hope to render valuable service to ORSA.

5. *Comments.* We hope ORSA will approve other student sections when enough interested people try to form a group. In doing so, our experience indicates that interest and guidance from the faculty is required to get the group through its growing pains. Prof. William S. Jewell has rendered our section invaluable assistance in many phases of our activities. Finally, a viable student chapter needs a nucleus of graduate students who will remain in school for two to three years. This would imply that a full-time graduate program must be available when a student chapter is organized.

SCHEDULE OF FUTURE SOCIETY MEETINGS

No.	*Dates*	*Location*	*Chairman*	*Deadline for abstracts**
27	May 6–7, 1965	Boston	DAVID M. BOODMAN 4 Linmoor Terrace Lexington 73, Mass.	Jan. 1, 1965
28	November, 1965	Houston	JAMES A. BIRDWELL P.O. Box 8423 Southmore Station Houston, Texas 77004	July 1, 1965
29	May, 1966	Los Angeles	JOHN E. WALSH System Development Corp. 2500 Colorado Avenue Santa Monica, Calif. 90406	Jan. 1, 1966
30	November, 1966	Raleigh	GEORGE E. NICHOLSON, JR. Dept. of Statistics Univ. of North Carolina Box 390 Chapel Hill, N. C.	July 1, 1966

* Abstracts of papers should be submitted to the Chairman of the desired meeting. Abstracts should be typed double-spaced following the form of the abstracts as printed in the BULLETIN.

EDITORIAL STYLE FOR ORSA MEETING AUTHORS

Invited and Contributed Authors at ORSA Annual and National Meetings can assist the Program Chairmen and the Editor of the *Bulletin* in assuring accurate communication by inserting their complete mail address, including ZIP Code, Department Code, and other identifying or required detail on all correspondence *and abstracts.* Editorial Policy of the *Bulletin* is to publish complete mailing addresses for all authors with each abstract. This action is necessary to prevent misdirection of the numerous world-wide requests for reprints of papers that occur after each meeting. Since neither the Editor of the *Bulletin*, The Program Chairmen, nor Society Officials have papers for distribution, requests must be referred directly to the authors. Such notice is published regularly in each Meeting Announcement. *It is therefore essential that complete author addresses be printed with abstracts, whether or not the author has papers for distribution.*

Authors can also facilitate preparation of their copy for the printer by preparing abstracts in double spaced format only, and by carefully preparing abstract titles (omitting session number to be assigned by the Program Chairman) in a format identical to that shown in current issues of the *Bulletin*. No underlining, quotation marks, or capital letters should be used to emphasize titles. To obtain a consistent style, this indication for the printer must be handled uniformly for all abstracts received, and is therefore done at one time and place by a single stylist. Inconsistently marked titles must be retyped.

THE ORSA COUNCIL MEETING

During the Society's Meeting in Montreal, the 1963–64 Council met on 26 May, and the new 1964–65 Council met on 27 May. At these sessions the following items were reported and discussed.

1. Consideration of ORSA cooperation with a proposal to establish an annual prize for classified papers on military operations research.

2. Approval of the Transportation Science Section's proposal to sponsor the "Third International Symposium on the Theory of Traffic Flow" in New York on 21–23 June 1965.

3. The Membership Committee reported its nominees for full Membership in the Society. A list of the new Members elected is shown below:

Elected at 25th National Meeting

MEMBER Grade Elections

Abrams, I. J.
Allen, Charles Anthony
Arora, Sant Ram
Asplund, Stanley E.
Avi-Itzhak, Benjamin
Bakanas, Victor E.
Barnes, Richard W.
Baum, Sanford
Bennett, Walter B.
Berger, Howard M.
Berman, Ray R.
Bernasconi, Farmin Asdrubol
Boehne, Raymond C.
Boyd, Lawrence E.
Brenner, Dr. Michael E.
Bright, Harold F.
Buffa, Dr. Elwood S.
Carter, Tasile T.
Clapham, Lawrence P.
Colombo, Anthony Angelo
Comer, Carlyle P.
Cook, Mr. Vincent M.
Cooper, Dr. Leon
Copenhagen, H. Wylls
Cullen, Francis James
Daniels, Everett J.
DePoy, Phil E.
DiGioia, Leo John

Doeh, Mr. Giyora
Durstine, Dr. Richard M.
Eckenrode, Robert T.
Edelman, Joel I.
Eldredge, David Leroy
Erdei, Michael J.
Fagan, Walter S.
Felix, Francis Joseph
Fiering, Myron B.
Flight, Robert Harold
Forsyth, Mr. O. Frederick
Gettinger, Mr. Harold
Gildea, Henry
Grayson, Charles J. Jr.
Greenberg, Harold
Greville, T. N. E.
Gross, Dr. Donald
Gruenberg, Hans S.
Hammer, Frederick S.
Harris, Britton
Herbach, Leon Howard
Heuser, William A. Jr.
Hoffenberg, Marvin
Hoffmayer, Karl J.
Homer, Eugene D.
Hosley, William M.
Hughes, John G.
Hynden, Carl M. Jr.
Intlekofer, John
Ippolito, Charles Joseph
Jaffe, Herbert
John, Dr. Floyd I.
Johnson, Peter J.
Jones, Philip Dudley
Eamiya, Eiichi
Kao, John H. K.
Kaplan, Seymour
Kirkland, John Thomas
Klein, Dr. Morton
Kollin, Mr. George
Koyanagi, Kenichi
Kranz, Frederick Henry
Lamb, Cdr. Harold M.
Leake, Lewis A.
Leimkuhler, Ferdinand F. Jr.
Lemus, Ferdinand
Lynam, Mr. William C.
Makower, Michael Stanley
Marbury, Fendall Jr.
Marceil, Jacques
Martino, Rocco L.
Mayzner, Dr. Mark S.
Mintz, Stanton E.
Morris, Robert H.
Mueller-Marbach, Deiner
McComb, Robert W.
McArthur, Dr. D. S.
Narevsky, Mr. A. D.
Naus, Joseph I.
Olmer, Dr. Francois J.
Palmer, Boyd Z.
Palmour, Vernon Eugene
Parker, C. E.
Peisakoff, Melvin Philip
Pengilly, Peter John
Pugh, Dr. George E.
Quackenboss, Frank B.
Redding, Joseph H.
Rieger, Willard R.
Roelike, Donald Arthur
Rogerson, George William
Rogin, Mr. Leo
Rosinsky, Martin
Saltzman, Sidney
Schafer, Tillman H.
Schultze, Donald P.
Shaffield, Joseph H.
Schoffner, Ralph M.
Short, Edward A.
Smith, Capt. Alwyn Jr., USN
Smith, DeAlton J.
Smith, Erwin Stuart
Sprague, C. Fremont III
Stankovich, Arthur
Stowell, Robert Luther
Sulit, Robert A.
Thatcher, Richard M.
Timm, Raymond Stanley
Uhlaner, J. E.
Vintiades, Polyvios C.
Wallace, Ricardo French Jr.

Webster, Francis M. Jr.
Weiser, Peter B.
Weiss, George Herbert
Weiss, Jerome
Wells, John F. Jr.
White, Lee R.
Willis, Kenneth E.
Woisard, Edwin Lewis
Wolfersberger, J. R.
Woods, Charles E.
Yewdall, Gordon Arthur
Zumwalt, Marvin White

4. The Fourth IFORS Meeting will be held at the Massachusetts Institute of Technology in August, 1966.

5. ORSA and TIMS jointly plan sponsorship of a session on operations research at the annual AAAS Meeting of 26–31 December.

6. The President was authorized to reactivate the National Problems Committee if that appears desirable.

7. Committees were appointed with terms to run until the Annual Meeting in 1965. Chairmen of the Committees are shown below:

Chairmen of Standing Committees

Membership Committee	Newton A. Ablahat
Publications Committee	Robert E. Machol
Education Committee	Harvey M. Wagner
Nominating Committee	Georges Brigham

MINUTES OF THE 1964 ANNUAL BUSINESS MEETING

1. The Twelfth Annual Business Meeting of the Operations Research Society of America was called to order by the *President*, Alexander M. Mood, at 5:25 p.m., 27 May 1964, in the MacKenzie Room of the Queen Elizabeth Hotel, Montreal, Canada.

2. The President pointed out that the Minutes of the 1963 Eleventh Annual Business Meeting had appeared on pages B-131 and B-132 of the 1963 volume of the BULLETIN of the Society.

IT WAS MOVED that the Minutes of the Eleventh Annual Business Meeting, as published in the BULLETIN, be approved.

MOTION PASSED.

3. The Secretary reported that in the period from May 1, 1963 to May 15, 1964:

a. Total membership in the Society increased by 403 (or 11%) from 3,756 to 4,159.

b. The number of non-member subscribers to OPERATIONS RESEARCH increased by 224 (or 8%) from 2,825 to 3,049.

4. The Treasurer summarized his report for 1963, noting that it appears in full in the Spring 1964 issue of the BULLETIN (pages B-80 through B-83).

5. The President read the Report of the Tellers for the 1963 election (Gordon D. Shellard, Arlene Icart, and Evelyn Jansen), showing the results of the mail ballot for officers for the year ending with the 1965 Annual Business Meeting and for Council Members for the three year term ending with the 1967 Annual Business Meeting. The following were reported by the tellers as having met the requirements for election:

George Shortley, *Vice-President and President-Elect*
Joseph H. Engel, *Secretary*
John E. Walsh, *Treasurer*
Murray Geisler, *Council Member*
David B. Hertz, *Council Member*

The President declared these Officers and Council Members elected.

6. The *Retiring President*, Alexander M. Mood, invited the incoming President to take the Chair.

7. The *Incoming President*, George E. Kimball, invited the Retiring President to report on the activities of the Society during his term as President. Alexander Mood accordingly made his report, and cited the Officers, Committees, Society Representives, Editors, and the Business Manager for their services to the Society. He noted that the Society now had an annual income of $100,000.

8. Hugh J. Miser, *Society Representative to IFORS*, announced that the Fourth International Conference of the Federation would be held at the Massachusetts Institute of Technology in Cambridge, in August, 1966.

9. The President called for any other business to be considered. There was none. Upon a motion duly put, seconded, and carried, the Meeting was adjourned at 5:35 p.m.

Gordon D. Shellard,
Secretary

Chairmen of Other Committees

Lanchester Prize Committee	Alexander M. Mood
Sections Committee	Robert Mirsky
Meetings Committee	Paul Stillson

Society Representatives

Representative to IFORS	Hugh Miser
Representative to NRC	Robert F. Rinehart
Representative to AAAS	Ralph W. Gerard Ellis A. Johnson

WASHINGTON OPERATIONS RESEARCH COUNCIL (WORC)

The 1964–65 Officers of WORC have been elected and are:

OFFICERS (And Trustees)

President	Dr. Alfred Blumstein
President-Elect	Mr. Boyd Ladd
Secretary	Dr. John Honig
Treasurer	Dr. Walter L. Deemer

Committee Chairmen

Membership	Mrs. Joann Langston
Program	Mr. Boyd Ladd

Publicity	Mr. Herbert Halbrecht
Newsletter	Mr. Winston C. Riley
Arrangements	Mr. Pierre Dowd
Lecture Series	Dr. Ed Cushen
Journal	Mr. Kenneth Webb
Seminars	Mr. J. A. Joseph

At-Large Members of the Board of Trustees

Mr. Thomas A. Goldman
Mrs. Joann Langston
Dr. William Dorfman
Dr. John P. Mayberry
Dr. David E. van Tijn

WORC Representative to WORC-ASPA

Dr. William Dorfman

ARGENTINE OPERATIONS RESEARCH SOCIETY

The Argentine Operations Research Society announces that the first Argentine Day of Operations Research will be held at Buenos Aires from August 19–21, 1964. The Argentine Society has extended invitations to ORSA Members for this occasion.

News and Announcements

HONOLULU MEETING, ORSA WESTERN SECTION

The Tenth Annual and First International Meeting of the Western Section of ORSA, Cosponsored by the Operations Research Society of Japan and the University of Hawaii (College of Business Administration), was held September 14–18, 1964, at the Princess Kaiulani Hotel, Waikiki, Honolulu, Hawaii.

Welcome addresses were delivered by MARTIN L. LUTHER, *President, ORSA Western Section,* and THE HONORABLE JOHN A. BURNS, *Governor of Hawaii.* The Keynote address was delivered by THE HONORABLE CHARLES J. HITCH, *Assistant Secretary of Defense, Comptroller,* entitled "Defense Programming—Three Years Later." A special invited address, "Decision Problems in Military R & D," was delivered by DR. ROBERT W. BUCHHEIM, *Chief Scientist of U.S. Air Force for 1964.*

GEORGE KIMBALL, *ORSA President,* was banquet speaker. THOMAS H. HAMILTON, *President, University of Hawaii,* offered a welcoming address, and KENICHI FUJIMORI, *Director, Operations Research Society of Japan,* read the luncheon address for DAIGORO YASUKAWA, *President, ORSJ.* The *Meeting Chairman* was JOHN E. WALSH, System Development Corporation.

MILITARY OPERATIONS RESEARCH SYMPOSIUM (MORS)

The 14th Military Operations Research Symposium, sponsored by the Office of Naval Research, will take place in San Diego, California on October 27, 28 and 29, 1964. The symposium is invitational, and will be classified SECRET. The theme of the symposium is "Operational Data—The Foundation for Operations Research Studies". In addition to general sessions at which contributed papers will be presented, there will be smaller working groups which will deal with the following topics:

Anti-Submarine Warfare
Arms Control and Disarmament
Command and Control
Education and Military Operations Research
High Speed Target Acquisition
Human Factors Intelligence Requirements
Limited Warfare
Logistics
Theories of Combat
Special Warfare and Counterinsurgency

(*For details of MORS organization, history, and details for registration, see Spring, 1964, BULLETIN. Ed.*)

THE INTERNATIONAL FEDERATION OF OPERATIONAL RESEARCH SOCIETIES

The Fourth International Conference on Operational Research

At the invitation of the Operations Research Society of America, the *Fourth Conference of the International Federation of Operational Research Societies* will take place at the Massachusetts Institute of Technology during late August 1966. As this notice is written the most likely dates appear to be August 29–September 2, 1966, with a small possibility of the earlier week of August 22–26 being chosen; the dates finally chosen will be announced shortly.

The program committee invites suggestions as to papers, subjects, and session chairmen appropriate for this conference. Any such proposals should be sent to the *Program Chairman*, MARTIN L. ERNST, *Arthur D. Little, Inc., Acorn Park, Cambridge, Massachusetts, U.S.A.* before December 1, 1964.

As was the case for the previous international conferences in this series, attendance will be by invitation only. A quota of 100 has been established for the ORSA delegation; members desiring to be considered for inclusion in this quota should write to the Society's IFORS Representative, HUGH J. MISER, *The MITRE Corporation, Box 208, Bedford, Massachusetts, 01730.*

Affairs of the Federation

The Fifth Annual Report of the Federation, prepared by its *Secretary*, PHILIP M. MORSE, lists seventeen Member Societies and two Kindred Societies, as shown in the accompanying table.

The Hellenic Operational Research Society (HELORS) has been formed in Greece; its *President* is MAJ. GEN. R. SPANOYANNAKIS (ret.), 27 Artemidos Str., Papagou, Athens, Greece. Its application for admission to IFORS is expected to be presented during 1964.

HUGH J. MISER
IFORS Representative

MEMBERSHIP IN IFORS AS OF JULY 1, 1963

Member Societies

Entered	*Country*	*Society*	*Membership*		*Voting Power*
			Total	*Qualified*	
1962	Argentina	SAIO	193	116	11
1960	Australia	AJCOR	143	75	9
1960	Belgium	SOGESCI	23	23	5
1960	Canada	CORS	347	124	11
1963	Denmark	DORS	66	51	7
1959	France	SoFRO	912*	205*	14
1962	Germany	DGU	276	128	11
1960	India	ORSI	80	80	9
1962	Italy	AIRO	135	46	7
1961	Japan	ORSOJ	870	150	12
1960	Netherlands	SOR	255	45	7
1960	Norway	NORS	62	54	7
1963	Spain	SEIO	72	25	5
1960	Sweden	SOAF	146	140	12
1963	Switzerland	SVOR	333	86	9
1959	United Kingdom	ORS	1,030	338	18
1959	United States	ORSA	3,756	1,215	35
	Totals		8,699	2,901	189

	Kindred Societies and Organizations	
1960	Air Lines Group	AGIFORS
1962	Kindred Society	TIMS

* Estimated

Notes: For complete names and addresses of the member societies, see the inside back cover of the current issue of *International Abstracts in Operations Research.* For definitions of "qualified membership" and "voting power," see the IFORS Statutes in this *Bulletin*, 7 (1959), pages B-37 to B-41.

SPANISH O.R. CONFERENCE

The Third Annual Conference of the Spanish Operations Research Society (SEIO) will be held in Barcelona, during the last week of January 1965. Members of the Operations Research Latin American Societies are kindly invited to attend the Conference and to co-operate sending their papers.

The *Executive Committee* is formed by Messrs. J. Torrens-Ibern (Chairman), E. Ruiz Palá (Treasurer), R. Companys (Secretary), L. Arocas and J. Béjar.

Titles and an abstract of papers should be sent to:

Prof. J. Torrens-Ibern
Seminario de Estadística Aplicada e Investigación Operativa
Escuela Técnica Superior de Ingenieros Industriales
Urgel, 187
Barcelona-11 (Spain)

before 31 August 1964. Papers in revised form should be sent before 30 November 1964.

INTERNATIONAL CONFERENCE ON O.R. AND SOCIAL SCIENCE

The 1964 Conference of the *Operational Research Society*, London, was held September 14–18, 1964, at Gonville & Caius College, Cambridge. This conference was supported by IFORS, and consisted of four major sessions as follows: (1) Organization and Control, the Study and Improvement of Present Systems, and Total Systems Deisgn; (2) Social Effects and Their Measurement, (3) Conflict Resolution and Control, (4) The Systems Concept as a Common Frame of Reference.

AGIFORS SYMPOSIUM

The Third AGIFORS Symposium (Airline Group, International Federation of Operational Research Societies) took place October 1–3, 1963, at Val Morin, Quebec, Canada. Twenty airlines were represented. Proceedings were published in January, 1964. Non-members may obtain single papers, while the supply lasts, by writing AGIFORS Information Officer, Dr. Marvin Rothstein, Director of Operations Research, American Airlines, Inc., 633 Third Avenue, New York, N.Y., 10017. Papers ranged from "The Early Reliability of Automotive Parts" by invited speaker M. Kamins, RAND Corporation, to "A Simulation Model of Airline Operations," by K. F. Jackson and J. U. M. Smith (BEA). Alec M. Lee is *Secretary-Treasurer* of the Airline Group at Trans-Canada Airlines, Place Ville Marie, Montreal 2, Quebec.

FULBRIGHT-HAYS ACT

Government grants for University Lecturing and Advanced Research have been announced under the above act through the *Committee on International Exchange of Persons, Conference Board of Associated Research Councils,* 2101 Constitution Avenue, Washington, D. C., 20418. Although applications for awards reportedly closed August 1, 1964, detailed offerings for future years and openings still available 1965–6 may be obtained from the address above, and a booklet listing possibilities in Europe, The Near East, South and East Asia, and Africa is available on request. *Inquiries concerning possible assignments in any country are welcomed, and scholars are invited to register their specific interests.*

AAAS MONTREAL MEETING

The 131st Annual Meeting of the *American Association for the Advancement of Science* will be held in Montreal, December 26–31, 1964. A call for papers has been issued. (See *Science,* May 22 1964, for complete preliminary announcement.) The meetings of the Society for General Systems Research are scheduled for this session, December 29–30. Speakers at this session will use the theme "Positive Feedback" as it applies to the following areas—international and political systems, business and economic systems, social systems, man and his internal systems, computation, control technology, and ecological systems. A panel discussion to integrate these presentations is also planned.

UNIVERSITY OF TORONTO O.R. COURSE

The University of Toronto has announced a Diploma Course in Operations Research for the 1964–5 Session. Designed to meet the needs of persons presently employed in industry, the course is a full-time day course running from September through April. The program consists of eleven course segments, ten of which must be taken. Admission requirements are a B.Sc. in engineering, science, or mathematics. Write: Secretary, Faculty of Applied Science and Engineering, University of Toronto, Toronto, Ontario. The academic fee for the program is $410.

THIRD CONGRESS ON AUTOMATIC CONTROL

The Third Congress of the *International Federation of Automatic Control* will be held in London, England, in June 1966. The manuscript deadline for papers from the United States is March 1, 1965. For further information contact: (AACC is American Automatic Control Council.)

DR. THEODORE J. WILLIAMS
Chairman, AACC Applications Committee
R and E Division
Monsanto Chemical Company
800 N. Lindbergh Blvd.
St. Louis 66, Mo.

DR. JOHN E. GIBSON
Chairman, AACC Theory Committee

Electrical Engineering Dept.
Purdue University
Lafayette, Indiana

DR. HERMAN R. WEED
Chairman, AACC Components Committee
Electrical Engineering Dept.
Ohio State University
Columbus 10, Ohio

ACM SOUTHEASTERN CONFERENCE

The Association for Computing Machinery Annual Southeastern Regional Conference will be held October 15–17, 1964 at the Atlanta Americana Motor Hotel, Atlanta, Georgia. For further information: I. E. PERLIN, *Georgia Institute of Technology, 225 North Avenue, Atlanta, Georgia 30332.*

SYSTEMS ENGINEERING CONFERENCE

The First Annual IEEE Systems Science Conference is to be held October 15–17 at the University of Pennsylvania. The advance registration fee of $8.00 should be sent to MR. H. G. SPARKS, *Moore School, University of Pennsylvania, Philadelphia, Pennsylvania,* by October 9. Registration forms and program may be obtained from Mr. Sparks. The program is divided into six sessions covering (1) Systems Theory, (2) Systems Optimization, (3) Systems Science Education, (4) Portable Concepts in Systems Science (Roundtable moderated by Dr. W. K. Linvill, Stanford University), (5) Systems Reliability, and (6) Systems Modeling.

U. S. BUDGET O.R. LISTINGS

(*The following note was submitted by* ED CUSHEN, IAOR Contributing Editor. *His Source was: U.S. Government Printing Office, "The Budget of the United States Government for the Fiscal Year Ending June 30, 1965: Appendix," Part III, pp. 963–1142, $6.25. The reader may wish to compare these figures with his own knowledge of the level of military and government O.R. activity.* Editor.)

Part III of the US budget Appendix tabulates, by job title, the number of Civil Service personnel in each of the Federal Agencies, for those employees holding ratings comparable to GS-14 and above. It is interesting to note that the number of such positions bearing the title, "Operations Analyst" or "Operations Research Analyst" has roughly doubled since 1961, at which time some 160 people were so designated. That the job titles do not exhaust the list of OR specialists, however, is shown by the following tabulation, subject to the usual errors of reading many pages of tables in fine print.

Department of the Army	0
Office of Civil Defense	2
Navy Department	
Office of Naval Research	11
Bu Weapons	30
Bu Ships	12

Bu Supp & Accounts	4
US Marine Corps	2
US Air Force	190
Department of Defense	50
Federal Aviation Agency	13
Atomic Energy Commission	4
Dept of Agriculture	3
Dept of Commerce	4
Health, Education & Welfare	2
US Coast Guard	1
	328

Among the many job titles that might, or might not, include significant OR activities one can find Analysts of all kinds (Management, Program, Logistics, Information Systems, etc.), Scientists, Advisors, Special Assistants, Branch Chiefs, Mathematicians, Statisticians, and Economists. There were 980 Systems Analysts listed, of which 904 were in NASA.

JOB OPPORTUNITIES

Headquarters, Defense Supply Agency anticipates openings in its Logistic Systems Design Division. Persons specially qualified in operations research, simulation, probability statistics, or automatic control engineering are invited to apply. Applicants should have facility in the use of mathematics and computers and in the design of experiments. Experience should preferably have been in the analysis or design of business-type systems pertaining to military logistics or civilian enterprise. Grades and salaries are open, commensurate with background.

Resumes and requests for additional information should be addressed to:

Chief, Logistic Systems Design Division
Headquarters, Defense Supply Agency
Cameron Station
Alexandria, Virginia 22314

PERSONAL NOTICES

The University of Pennsylvania has announced that Russell L. Ackoff has been appointed Professor of Operations Research and Statistics. Joining Prof. Ackoff at Penn are Glen D. Camp, Professor, S. Sankar Sengupta, J. Sayer Minas, Associate Professors, Frank Benson, Visiting Associate Professor, Miles W. Martin, Jr., Assistant Professor, Eli S. Marks, Research Associate, and William W. Abendroth, Lecturer. This group was formerly with the Operations Research Group, Case Institute of Technology, where Dr. Ackoff was Director.

Robert F. Rinehart has returned to Case Institute of Technology as Professor of Mathematics after a two-year leave of absence as Director of Research of the Weapons Systems Evaluation Group of the Department of Defense.

Paul Somerville has been appointed Chairman of the Graduate Department of Mathematics, Brevard Engineering College, Melbourne, Florida. Dr. Somerville is also head of the Analytical Support Unit of Systems Analysis at RCA's Missile Test Project at Cape Kennedy.

Dr. Tibor Fabian, formerly Executive Vice-President, has been elected President of Mathematica.

Douglas Aircraft announces the appointment of Dr. Carroll L. Zimmerman, Sr., as Director of Aerospace Science, and also that Dr. William W. Fain, his wife, Dr. Janice S. B. Fain, and Dr. A. G. Aswad have joined the aerospace sciences department.

The United States Air Force announces the following appointments in Operations Analysis, Office of the Vice Chief of Staff, Headquarters, United States Air Force: To Deputy Chief, Dr. Walter L. Deemer; to Chief, Research Team, Dr. John P. Mayberry; to Chief, General War Team, Bergen R. Suydam.

Murray Greyson has been appointed Deputy Director of the Operations Model Evaluation Group, Air Force (OMEGA), operated by Technical Operations Research for the Air Force.

Dr. H. N. Laden has been named Director, Data Systems, Chesapeake & Ohio Railway Company—Baltimore & Ohio Railroad Company. The C & O and the B & O are affiliated and coordinating numerous activities during the period of control as a step toward merger.

S. J. Deitchman has been promoted to the position of Special Assistant to the Deputy Director, Tactical Warfare Programs, Office of the Director of Defense Research and Engineering, Institute for Defense Analysis.

The Social Security Administration of the Department of Health, Education, and Welfare, announces the appointment of John Hunton Moss as Operations Research Director in the Central Planning Staff.

Dr. Alex L. Hart, formerly Executive Director, New York-New Jersey Transportation Agency, has joined H. Zinder & Associates, New York City, as Director of Transportation Activities.

Sidney Zimmerman has been appointed to the post of corporate vice president, finance, at Operations Research Incorporated.

The following appointments have been announced at the Center for Naval Analysis (CNA): Dr. Leo S. Mason has been awarded a Franklin Institute Scholarship as part of the CNA professional development program. Frank P. Randazzo has joined the Operations Evaluation Group of CNA. Frederick W. Cleaver has been assigned to the Naval Warfare Analysis Group. Donald E. Muir has joined the Operations Evaluation Group. CNA. CNA also announced that fifteen graduate scientists have been accepted for positions as summer interns. These men and their disciplines are as follows: Robert K. Ankrom, Harvard, economics; Barry Raymond Chiswick, Columbia, economics; Philip Lee Cohen, Stanford, economics; Peter Doeringer, Harvard, economics; Peter Enis, George Washington, mathematics; Richard Garrett, Northwestern operations research; Kenneth Hoffman, Harvard, mathematics; Ann Carolyn Johnson, Stanford, mathematics; Uwe Koehn, University of Illinois, statistics; William Martin Landes, Columbia, economics; Eric Jon Olson, Duke, economics; Richard Ridings, University of Wisconsin, electrical engineering; Edward Gordon Sanders, Yale, economics; Robert Alan Schwartz, Columbia, economics; William Hoyt Witherell, Princeton, economics. Dr. Peter A. Cole has been named Director of the Institute of Naval Studies (INS). (CNA is composed of the Institute of

Naval Studies, the Operations Evaluation Group, and the Naval Warfare Analysis Group and is a division of the Franklin Institute of Pennsylvania.)

The Institute for Defense Analysis (IDA) announces the following appointments: DR. STANLEY WINKLER to the professional staff and JOSEPH A. NAVARRO to the Research and Engineering Support Division.

The Research Analysis Corporation (RAC) announces the following appointments: DANIEL E. COWGILL, JUDITH A. BANCROFT, GILBERT B. ROZRAN, JANE-RING FITZ CRANE, JOHN R. BOSSENGA, GEORGE H. SCHAEFER, JACOB N. JOHNSON and EMIL M. SZTEN, technical staff members.

DR. LYNN H. RUMBAUGH, 60, long a senior staff member and Research Director at the Research Analysis Corporation died March 11, 1964 at his home in Bethesda, Maryland. Dr. Rumbaugh joined the predecessor to RAC—the Operations Research Office of The Johns Hopkins University—in 1950, and his subsequent responsibilities included serving as acting Director during the transition period in 1961, when ORO became RAC.

MURRAY L. EISENBERG, 45, member of the technical staff at Research Analysis Corporation, died Tuesday, July 7, 1964, of cancer at Holy Cross Hospital, Silver Spring, Maryland. Mr. Eisenberg began his career as a journalist, became an economist with the War Production Board, and served as head of the management statistics branch, Bureau of Ships, Department of the Navy, before he joined RAC.

TORE M. MANIELSEN has been appointed Head of Operations Research at *Elektriska Svetsnings AB* (*ESAB*), Gothenburg, Sweden.

ELIEZER NADDOR has been promoted to Professor of Operations Research, Johns Hopkins University. He is presently on a Fulbright Grant to lecture on Operations Research at the Helsinki School of Economics and at the Swedish School of Economics, Helsinki, during the academic year 1964–5.

ROBERT E. MACHOL is Head, Department of Systems Engineering, College of Engineering, University of Illinois, Chicago. He resides at 741 Sheridan Road, Evanston, Illinois.

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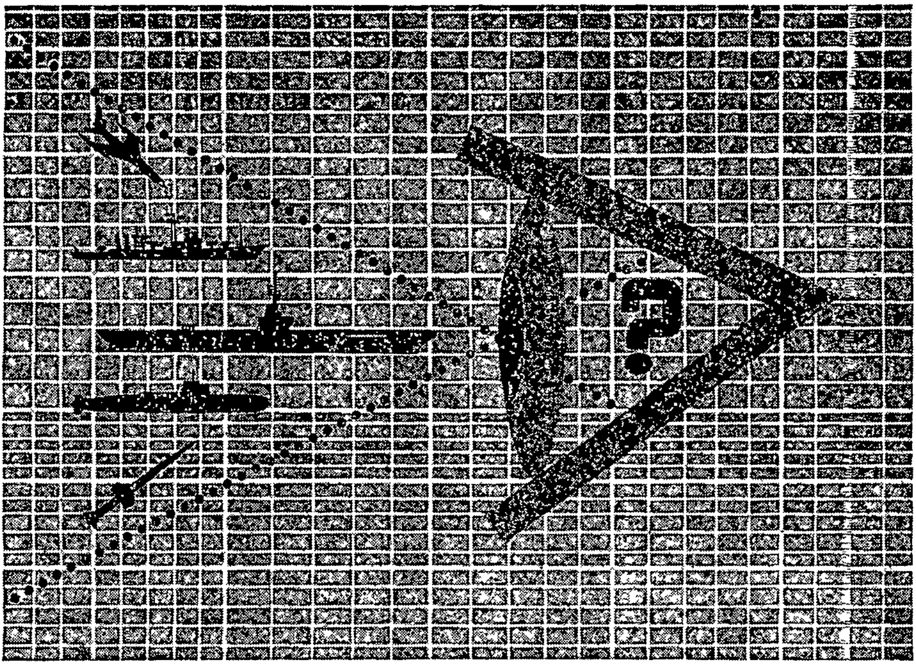

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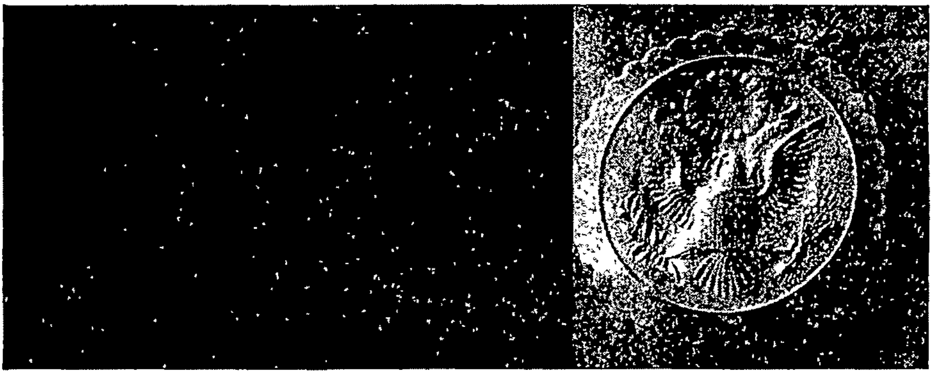

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